BIOSCREEN Modeling of Total Petroleum Hydrocarbons at the Old Navy Fuel Farm Naval Air Station, Brunswick, Maine

Contract No. N62472-92-D-1296

Prepared for

Department of the Navy
Engineering Field Activity Northeast
Naval Facilities Engineering Command
10 Industrial Highway
Mail Stop No. 82
Lester, Pennsylvania 19113-2090

Prepared by

EA Engineering, Science, and Technology
Southborough Technology Park
333 Turnpike Road, Route 9
Southborough, Massachusetts 01772

February 2003
FINAL
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QUALITY REVIEW STATEMENT

Contract No. N62472-92-D-1296
Contract Task Order No. 0035
Activity: Naval Air Station, Brunswick, Maine

EA Project No.: 29600.35

Description of Report/Deliverable:

BIOSCREEN Modeling of Total Petroleum Hydrocarbons at the Old Navy Fuel Farm, Naval Air Station, Brunswick, Maine

EA CTO Manager: Alexander C. Easterday, P.G.

In compliance with EA's Quality Procedures for review of deliverables outlined in the Quality Management Plan, this final deliverable has been reviewed for quality by the undersigned Senior Technical Reviewer(s). The information presented in this report/deliverable has been prepared in accordance with the approved Implementation Plan for the Contract Task Order (CTO) and reflects a proper presentation of the data and/or the conclusions drawn and/or the analyses or design completed during the conduct of the work. This statement is based upon the standards identified in the CTO and/or the standard of care existing at the time of preparation.

Senior Technical Reviewer

2/20/03

Douglas E. McClure, P.E.
Senior Engineer

(Date)

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1. INTRODUCTION

EA Engineering, Science, and Technology, under Contract No. N62472-92-D-1296 with Engineering Field Activity Northeast, Naval Facilities Engineering Command, completed an analysis of the predicted natural attenuation of total petroleum hydrocarbons (TPHs) in ground water at the Old Navy Fuel Farm, Naval Air Station, Brunswick, Maine (NAS Brunswick). The Old Navy Fuel Farm is located on the northeast portion of NAS Brunswick. EA conducted fate and transport modeling as per discussions with the Navy and Maine Department of Environmental Protection (MEDEP) representatives held on 12 June 2001, and follow-up discussions with MEDEP on 11 July 2001.

The original intent was to use the RISKPRO SESOIL Model (Version 2.5) to calculate the vertical transport of residual petroleum compounds from the vadose zone to the water table. Some residual TPH concentrations remained in vadose zone soil following remedial excavation of soil that contained elevated concentrations of TPHs. Remedial soil excavation was performed by Foster Wheeler Environmental Corporation from September through November 2000 (Foster Wheeler 2002). After EA completed a review of recent subsurface data for the site, the bulk of the remaining residual mass was found to occur below the water table. Based on these data, the SESOIL model was not considered appropriate and, therefore, was not used as this model is intended for the vadose zone only. Instead, BIOSCREEN R.1.4 (Newell and McLeod 1997) was used to evaluate residual TPH in the saturated zone. The use of the BIOSCREEN model was approved by MEDEP on 11 July 2001.

1.1 REPORT ORGANIZATION

The remaining sections in this report address the following topics:

- **Section 2 – Site History**—Brief summary of historical environmental site investigations and remedial actions conducted at the Old Navy Fuel Farm during the period 1990-2001.
- **Section 3 – Model Input Parameters**—Detailed discussion of the BIOSCREEN input parameter selection process.
- **Section 4 – Model Calibration**—Detailed discussion of the BIOSCREEN model calibration process, using historical analytical data for calibration constraints.
- **Section 5 – Model Results**—Summary of BIOSCREEN model results and predicted TPH fate and transport in the saturated zone at the Old Navy Fuel Farm.
- **Appendix A**—BIOSCREEN calibration data.

- **Appendix B**—BIOSCREEN TPH-gasoline range organic (GRO) data.
- **Appendix C**—BIOSCREEN TPH-diesel range organic (DRO) data.
- **Appendix D**—Model Sensitivity Analysis.
- **Appendix E**—Comments and EA's Response to Comments from MEDEP on the Draft Report.

2. SITE HISTORY

The Old Navy Fuel Farm site is located on the northeast portion of the NAS Brunswick grounds, and is bounded on the south by Fitch Avenue, on the west by 6th Street, and to the north and east by undeveloped land. The site was previously used as a petroleum bulk storage facility and was decommissioned in 1993. Existing surface grade consists of a level field of grass. Figure 1 provides the NAS Brunswick site location map. Figure 2 provides current site conditions at the Old Navy Fuel Farm. The following sections provide a brief summary of geologic conditions, environmental site investigations, and remedial actions conducted at the Old Navy Fuel Farm during the period 1990-2001.

2.1 SITE GEOLOGIC CONDITIONS

Previous hydrogeologic investigations (O'Brien & Gere 1990, 1992) revealed that the site is underlain by a sandy deposit (upper sand) which is continuous, and is underlain by a glacio-marine silty clay deposit (designated as the Presumpscot Clay by the Maine Geologic Survey). The sandy deposit thickness ranges from 2.5 to 9 ft with thicker zones located at the northwest section of the site. The ground-water table occurs in the sandy zone and flows generally southeasterly parallel to the surface topography. Figure 3 provides the latest available interpreted ground-water contour map based on monitoring well gauging data collected during December 2000 (EA 2001a).

2.2 HISTORICAL PETROLEUM BULK STORAGE AND ENVIRONMENTAL INVESTIGATION SUMMARY

Prior to decommissioning in 1993, the Old Navy Fuel Farm consisted of two separate petroleum bulk storage tank farms that, together, included nine mounded underground storage tanks. The older, western tank farm included five underground storage tanks, previously identified as underground storage tanks T-101 through T-105. Underground storage tanks T-101 through T-103 were 100,000-gal capacity tanks used for storage of petroleum sludge, unleaded gasoline, and aviation gasoline, respectively. At some time prior to April 1990, underground storage tanks T-101 through T-103 were taken out of service. Underground storage tanks T-104 and T-105 were both 25,000-gal capacity tanks used for storage of ethylene glycol. The newer, Eastern Fuel Farm included four underground storage tanks, previously identified as underground storage tanks T-202 through T-205. Each of these underground storage tanks were 567,000-gal capacity tanks used for storage of JP-5. All underground storage tanks, piping, and associated appurtenances were removed during facility decommissioning completed in 1993.

Previous environmental investigations (O'Brien & Gere 1990, 1992) identified a dissolved-phase hydrocarbon plume located in the east-central portion of the Old Navy Fuel Farm (east of 7th Street) which appeared to originate in the vicinity of former JP-5 underground storage tank T-202. This plume previously extended downgradient from the former location of T-202 toward

the south-southeast and consisted primarily of benzene, toluene, ethylbenzene, and xylene (BTEX) compounds. Figure 4 provides a photocopy of the original O'Brien & Gere Engineers, Inc. interpreted dissolved-phase total BTEX concentration isopleth map based on ground-water samples collected during April 1990 (O'Brien & Gere 1990). In November 1991, a supplemental ground-water sampling event confirmed the continued presence of this dissolved-phase hydrocarbon plume (O'Brien & Gere 1992).

In October and November 1993, HRP Associates, Inc., Plainville, Connecticut, completed a ground-water sampling event at the Old Navy Fuel Farm following facility decommissioning and associated underground storage tank removals, with the exception of T-202 and T-203 (HRP Associates, Inc. 1993). The results of these ground-water sampling events indicated that the dissolved-phase BTEX plume located in the Eastern Fuel Farm had exhibited a significant reduction in total BTEX concentrations with little or no indication of plume migration. The extent of the dissolved-phase BTEX plume did not exhibit significant change from April 1990 to October-November 1993. However, the maximum dissolved-phase BTEX concentration decreased from greater than 20,000 µg/L in 1990 to 4,777 µg/L in 1993, with similar reductions in dissolved-phase BTEX concentrations throughout the plume area. These observations document the occurrence of significant natural attenuation of petroleum hydrocarbons at the Old Navy Fuel Farm.

It should be noted that results from the ground-water sample results collected by both O'Brien & Gere Engineers, Inc. and HRP Associates, Inc. during 1990-1993 indicated the presence of a separate dissolved-phase hydrocarbon release area in the Western Fuel Farm (west of 7th Street). However, insufficient samples were collected to delineate the extent of the western dissolved-phase hydrocarbon plume at these times.

2.3 SUMMARY OF REMEDIAL PROGRAMS AT THE OLD NAVY FUEL FARM

Remedial programs completed at the Old Navy Fuel Farm included operation of a soil vapor extraction/air sparging system as a biosparging system (i.e., low-flow air injection without vapor extraction) during August 1996 – December 1998, active soil vapor extraction/air sparging system operation (with ground-water recovery) during March through July 1999, biosparging system operation during September 1999 through August 2000, and remedial excavation of residual source area soils during September through November 2000. The following sections provide brief summaries of each remedial program outlined above.

2.3.1 Biosparging System Operation (August 1996 – December 1998)

A soil vapor extraction/air sparging system for remediation of vadose and saturated-zone hydrocarbon contamination at the Old Navy Fuel Farm was designed by HRP Associates, Inc. Soil vapor extraction/air sparging system installation was completed in early 1996 by OHM, Inc. In June 1996, a pre-start investigation was conducted during which it was found that the water table elevation was at or above the level of the lateral soil vapor extraction intake screens,

preventing operation of the soil vapor extraction system. Since effective operation of the soil vapor extraction system was not possible, the Navy obtained approval from MEDEP to operate the system as a biosparging system to enhance *in situ* biodegradation of petroleum hydrocarbons. The Old Navy Fuel Farm biosparging system was activated on 8 August 1996 with the injection of compressed air into both lateral soil vapor extraction screens and air sparging wells throughout the eastern and western dissolved-phase plume areas.

The biosparging system was operated until December 1998, at which point the system was deactivated to allow completion of system modifications for soil vapor extraction operations. Figures 5, 6, and 7 provide interpreted BTEX, TPH-GRO, and TPH-DRO concentration isopleth maps, respectively, based on baseline ground-water samples collected during 7-8 August 1996, prior to the August 1996 through December 1998 biosparging operational period. Based on a comparison of ground-water samples collected prior to and following this biosparging period (i.e., 7-8 August 1996 baseline sampling event and 15-18 June 1999 sampling event, respectively), a significant reduction in both the extent and concentration of dissolved-phase BTEX concentrations was exhibited throughout the Old Navy Fuel Farm. This observation is supported by five additional ground-water sampling events conducted bi-annually during the biosparging system operational period (EA 1997a, 1997b, 1998a, 1998b, 1999).

2.3.2 Soil Vapor Extraction/Air Sparging System Operation (March–July 1999)

In an effort to increase the effectiveness of active remedial operations at the Old Navy Fuel Farm, modifications were made to allow operation of the soil vapor extraction system (which had previously been inoperable due to elevated water table conditions). The modifications included installation of a dual-phase extraction and separation system and were completed during the period from October 1998 through March 1999. The soil vapor extraction/air sparging system was activated on 9 March 1999 and continued operation until 16 July 1999, when the vapor-phase granular activated carbon emission treatment system became saturated. During the active soil vapor extraction/air sparging period, approximately 600 lb of petroleum hydrocarbons were removed from the site (EA 2000a). Additional *in situ* treatment (i.e., biodegradation) due to enhanced oxygen delivery (both from active air sparging and vadose zone air entrainment) is likely to have occurred but was not quantified.

Following the rapid saturation of the vapor-phase granular activated carbon emission treatment system, the Navy performed an economic analysis of various remedial alternatives and identified excavation of residual source area soils followed by natural attenuation as the most suitable remedial strategy for the Old Navy Fuel Farm. During the interim period prior to remedial soil excavation (i.e., September 1999 – September 2000), the biosparging system was re-activated.

2.3.3 Remedial Soil Excavation Program

From 9 August to 2 September 1999, a direct-push investigation was completed to delineate the remaining petroleum-impacted source areas and to identify remedial excavation target areas (EA 2000b). The results of the direct-push investigation were used to identify areas for subsequent test pit excavation completed by Foster Wheeler (Foster Wheeler 2002). Based on the results of the direct-push and test pit sampling programs, excavation target areas were identified.

During 11 September – 7 November 2000, Foster Wheeler removed approximately 14,677 tons of petroleum-impacted soil from the Old Navy Fuel Farm site. Confirmatory sampling indicated that residual petroleum-impacted soil remains onsite based on excavation bottom and sidewall samples, at concentrations ranging from non-detect to 840 mg/kg TPH (reported as cumulative TPH-DRO and TPH-GRO).

During the test pitting and soil excavation process, the existing soil vapor extraction/air sparging system field components were either removed from the site or abandoned in-place. Existing monitoring wells and well points located within the Old Navy Fuel Farm fence line were decommissioned during 23-30 April 2001 in accordance with MEDEP Solid Waste Management Rules (EA 2001b). Therefore, ground-water sampling events conducted after 30 April 2001 include only monitoring wells located downgradient of the Old Navy Fuel Farm fence line. These monitoring wells serve as sentinel wells to assess the potential for offsite migration of dissolved-phase petroleum compounds. The locations of the decommissioned wells are depicted on Figure 2.

2.3.4 Post-Remedial Excavation Ground-Water Sampling

Following completion of the remedial soil excavation program, EA collected ground-water samples from sentinel monitoring wells located downgradient from the Old Navy Fuel Farm fence line during December 2000 and May and October 2001. These ground-water samples were analyzed for TPH-GRO and TPH-DRO by MEDEP Methods 4.2.17 and 4.2.25, respectively. Figures 8, 9, and 10 provide tag maps for analytical sampling results from the December 2000, May 2001, and October 2001 ground-water sampling events, respectively.

During the December 2000 ground-water sampling event, dissolved-phase TPH-GRO was detected at only 2 of 14 monitoring well locations (MW-NASB-054 and MW-NASB-061R). Each of these monitoring wells was located within the Old Navy Fuel Farm fenceline in the vicinity of the western source area. Concentrations of dissolved-phase TPH-GROs reported at these locations during December 2000 ranged from 24 to 45 µg/L, each below the MEDEP stringent cleanup goal. During the December 2000, May 2001, and October 2001 ground-water sampling events, TPH-GRO was not detected at any upgradient or downgradient locations to the Old Navy Fuel Farm. During May and October 2001, ground-water samples were not collected from locations within the Old Navy Fuel Farm fenceline.

During the December 2000 and October 2001 ground-water sampling events, dissolved-phase TPH-DRO was not detected at monitoring well locations upgradient to the Old Navy Fuel Farm (including monitoring wells MW-NASB-062 and MW-NASB-213). These monitoring wells were not sampled during May 2001. Ground-water samples were collected from within the Old Navy Fuel Farm fenceline only during the December 2000 sampling event. Dissolved-phase TPH-DRO was detected at concentrations of 700 and 190 µg/L at monitoring wells MW-NASB-061R and MW-NASB-054, respectively. The relatively elevated TPH-DRO concentration reported at MW-NASB-061R was collected from the central region of the western source area.

During the December 2000, May 2001, and October 2001 ground-water sampling events, dissolved-phase TPH-DRO was detected at concentrations ranging from non-detect to 400 µg/L at several monitoring wells located downgradient to the Old Navy Fuel Farm. As discussed previously, TPH-GRO was not reported at these locations. Migration of ppb concentrations of TPH-DRO to the downgradient monitoring wells may have occurred since TPH-GRO within the source area was likely preferentially biodegraded relative to TPH-DRO compounds.

3. MODEL INPUT PARAMETERS

BIOSCREEN R.1.4 (Newell and McLeod 1997), a two-dimensional ground-water flow and solute transport analytical model, was used to assess the transport and attenuation of TPH compounds in ground water and the residence of TPH compounds in residual source areas at the site. The goal of the modeling was to estimate the period of time that ground-water concentrations of TPH would remain greater than the state regulatory goal of 50 parts per billion (µg/L). TPH compounds in the subsurface attenuate (mostly through biodegradation) with time. BIOSCREEN is an effective tool for modeling hydrocarbon plumes affected by attenuation processes, including advection, dispersion, adsorption, and biodegradation. Additional information regarding the BIOSCREEN model theory is provided in the BIOSCREEN User's Manual (Newell and McLeod 1997).

The following sections provide specific information regarding the selection of appropriate input parameters for the BIOSCREEN model at the Old Navy Fuel Farm. Site-specific parameter input values, when available, were used preferentially to reference-based parameter input values for typical hydrocarbon release sites. The modeling effort required several parameter assumptions for input. EA used available information and data for the parameters and reasonable assumptions in the model development.

3.1 SOURCE AREAS AND DISSOLVED-PHASE HYDROCARBON PLUMES

Based on historical analytical data and recently completed (i.e., 1999-2000) direct-push and test pit soil sampling programs, two primary petroleum hydrocarbon source areas have been identified at the Old Navy Fuel Farm. These locations will be referred to as the eastern and western source areas. Both ground-water and soil sampling data results have indicated the potential presence of multiple release locations within each area that may have resulted from historical bulk petroleum storage operations (i.e., 1951-1993) and/or regrading operations following facility decommissioning activities in 1993-1994. For modeling purposes, the apparent release areas have been composited and positioned as consolidated residual sources in the center of the eastern and western dissolved-phase plumes, resulting in two distinct modeling areas. Therefore, the model results serve to predict the temporal persistence and overall migration potential for dissolved-phase TPH at the Old Navy Fuel Farm. The model results are not intended to represent specific plume concentration patterns within the Old Navy Fuel Farm fence line.

The most recent ground-water sampling event during which sufficient monitoring points were available to delineate the extent of the TPH-GRO and TPH-DRO plumes was completed during June 1999 (EA 1999). Figures 11 and 12 depict the interpreted dissolved-phase TPH-GRO and TPH-DRO plumes based on ground-water samples collected during 15-18 June 1999. The interpreted dissolved-phase concentration isopleths depicted on Figures 11 and 12 have been augmented using additional analytical data collected during the December 2000 and May and

October 2001 ground-water sampling events. These more recent sampling events provide data only from sentinel well locations and serve to define the leading edge of the dissolved-phase plume. Therefore, the June 1999 sampling event remains the most recent period during which the extent of the dissolved-phase plumes within the Old Navy Fuel Farm fence line were delineated. It should be noted that the June 1999 analytical data (i.e., collected prior to the September-November 2000 soil excavation program) likely over-estimate the current extent and concentration profile of the TPH plumes within the fence line, resulting in a conservative assumption of current site conditions.

The eastern source area is centered in the east-central portion of the Old Navy Fuel Farm and appeared to originate in the vicinity of former JP-5 underground storage tank T-202. A possible second release location for the eastern source area may have been located south of former underground storage tank T-204. These locations are in the vicinity of remedial soil excavation areas designated by Foster Wheeler as B15, B17, C16, D11, E14, E17, and G14, located to the east of 7th Street. The area-weighted average maximum sidewall soil concentration (124 mg/kg, post-excavation) from these remedial excavation locations was used for estimating residual soil TPH concentrations at the eastern source area. The area-weighted average maximum sidewall soil concentration (124 mg/kg) was determined by dividing the product of each remedial excavation "footprint" (ft^2) and maximum confirmatory sidewall soil concentration (ranging from 6.1 to 426 mg/kg) by the sum of the remedial excavation area footprints (ft^2). The calculations used to develop average residual TPH soil concentrations in the consolidated source areas are provided in Table 1.

The western source area is centered in the northwest-central portion of the Old Navy Fuel Farm around the former location of Building 206 (Filter Separator) south to the former locations of ethylene glycol storage tanks T-104 and T-105. This area corresponds to soil excavation areas designated by Foster Wheeler as B7, G7, H8, I6, TP6, TP7/D7, and TP24, located to the west of 7th Street. The area-weighted average maximum sidewall soil concentration (246 mg/kg, post-excavation) from these remedial excavation locations was used for estimating residual soil TPH concentrations at the western source area. The area-weighted average maximum sidewall soil concentration (246 mg/kg) was determined by dividing the product of each remedial excavation "footprint" (ft^2) and maximum confirmatory sidewall soil concentration (ranging from 0.0 to 700 mg/kg) by the sum of the remedial excavation area footprints (ft^2).

As stated above, approximate consolidated source release areas were used for modeling purposes. The residual source areas for the eastern and western dissolved-phase hydrocarbon plumes were estimated to correspond to the >100 µg/L (TPH-GRO) and >1,000 µg/L (TPH-DRO) interpreted dissolved-phase isopleths provided on Figures 11 and 12, respectively. The 100 µg/L and 1,000 µg/L interpreted dissolved-phase isopleths were used for estimating the consolidated residual source areas for the TPH-GRO and TPH-DRO models, respectively, since these concentration intervals were most consistent with the indicated historical release areas. The approximate consolidated source release locations were developed based on existing ground-water analytical data and confirmatory samples collected during the remedial excavation

program. Average TPH concentrations provided in Table 1 (based on the area-weighted maximum sidewall soil concentrations from post-excavation samples) were used to estimate residual soluble mass for both TPH-GRO and TPH-DRO simulations. Since no information was available to differentiate between TPH-GRO and TPH-DRO in confirmatory soil sample analytical data, the overall TPH value was used for both hydrocarbon ranges. The resulting model predictions will, therefore, be conservative with respect to the estimated soluble mass remaining in the source areas.

3.2 BIOSCREEN INPUT PARAMETERS

This section provides detailed descriptions of the BIOSCREEN model input parameter selection process for modeling dissolved-phase hydrocarbon behavior at the eastern and western source areas. Where required, type-specific input parameters are provided for both TPH-GRO and TPH-DRO models. The following subsections are based on the BIOSCREEN parameter input format and are presented in the order in which parameter types are entered in the BIOSCREEN software package. As stated previously, site-specific input parameters were used to the extent possible based on available data from the Old Navy Fuel Farm. References have been provided for site-specific model input parameters and for estimated values where site-specific data were not available.

3.2.1 Hydrogeology

Hydrogeologic effects are modeled in BIOSCREEN using seepage velocity (Vs). Seepage velocity represents the speed at which ground water moves through porous media, and is calculated by multiplying hydraulic conductivity by hydraulic gradient and dividing by the effective porosity. The seepage velocity value strongly influences the estimated length of ground-water plumes and the estimated time to reach dissolved-phase remedial goals. Due to this influence and the high variability of seepage velocity in the field, use of actual site data to calculate seepage velocity is strongly recommended (Newell and McLeod 1997).

BIOSCREEN calculates a seepage velocity value based on user provided values for hydraulic conductivity (K), hydraulic gradient (i), and effective porosity (n_e). For each of these hydrogeologic parameters, site-specific values were available from previous environmental site investigations conducted at the Old Navy Fuel Farm, as detailed in Table 2.

3.2.2 Dispersion

Dispersion refers to the process whereby a plume will spread out in a longitudinal direction (along the direction of ground-water flow), transversely, and vertically downward due to mixing in the aquifer. Selection of dispersivity values is a difficult process, given the impracticability of measuring dispersion in the field. Therefore, estimation techniques based on the distance from the plume source to the measurement point (model scale) are typically used for modeling purposes.

BIOSCREEN user inputs are required for longitudinal, transverse, and vertical dispersivity (αx, αy, and αz, respectively) or the user may input a value for the estimated hydrocarbon plume length (Lp) to allow the software to estimate the dispersivity factors. Since specific dispersivity values were not available for the Old Navy Fuel Farm, estimated plume lengths were entered for both the eastern and western source areas and for both TPH-GRO and TPH-DRO dissolved-phase plumes based on existing ground-water analytical data. These estimates were refined during the calibration process in accordance with directions provided with the BIOSCREEN users manual. The estimated plume length values are provided in Table 2. Calibration procedures are detailed in Section 4.

3.2.3 Adsorption

BIOSCREEN calculates an adsorption value based on the site-specific soil bulk density (ρ), contaminant partition coefficient (Koc), soil fractional organic carbon content (foc), and effective porosity (n_e), or the user may manually set a retardation factor (R) value. The retardation factor represents the ratio of the ground-water seepage velocity to the migration rate of organic chemicals. A retardation value of 2 for a given compound indicates that if the ground-water seepage velocity is 100 ft/year, then the compound will migrate approximately 50 ft/year. The degree of retardation depends on both aquifer and constituent properties. Retardation factors generally range from 1.0 to 2.0 for BTEX constituents in typical shallow aquifers, but are dependent on soil type, and are often higher for more hydrophobic compounds (Newell and McLeod 1997).

Since site-specific information was not available for the soil bulk density, partition coefficient, and fractional organic carbon, a retardation value of 1.5 was selected as the model input parameter for TPH-GRO surrogate compounds. This value is the median of suggested values (ranging from 1 to 2) provided in the BIOSCREEN users manual for BTEX modeling in shallow aquifers. For TPH-DRO, a retardation factor of 2.1 was selected based on calculations for TPH-DRO at a site with similar hydrogeologic and petroleum release characteristics, located at Vandenberg Air Force Base, Vandenberg, California (Concurrent Technologies Corporation 1999).

3.2.4 Biodegradation

BIOSCREEN uses an analytical solute transport model with two options for simulating *in situ* biodegradation: first-order decay and instantaneous reaction. BIOSCREEN will predict the maximum extent of plume migration and persistence of dissolved-phase hydrocarbons based on both modeling options.

In addition to the first-order decay and instantaneous reaction models, BIOSCREEN also provides a contaminant transport assessment based on a "no-degradation" model. The no-degradation model predicts the movement of contaminants in the ground water under the assumption that biodegradation does not occur within or downgradient to the source area. The

only attenuation mechanisms that are considered under the no-degradation model are dilution; dispersion in the longitudinal, transverse, and vertical directions; and adsorption of the contaminants to the soil.

Based on site-specific biodegradation indicator parameters previously assessed at the Old Navy Fuel Farm (including electron acceptor demand, microbial enumeration studies which quantified total heterotrophic and hydrocarbon degrading bacteria, and measurements of biodegradation by-products such as methane and carbon dioxide), it has been established that biodegradation of residual petroleum hydrocarbons has been occurring at the site. In addition, dissolved-phase contaminant trend data collected over a 10-year period (1991-2001) indicate that the no-degradation model is not applicable for predicting migration potential at the Old Navy Fuel Farm, since the actual extent of contaminant migration is far less than predicted under the no-degradation model. Therefore, the no-degradation model predictions provided by BIOSCREEN are not discussed further, however, predicted trend lines are included on the graphs in Appendix B and Appendix C for reference purposes only.

3.2.4.1 First-Order Decay Model

The first-order decay model assumes that the solute degradation rate is proportional to the solute concentration (i.e., higher contaminant concentrations are simulated with higher degradation rates). This is a conventional, albeit conservative, method for simulating biodegradation of dissolved-phase hydrocarbon plumes.

The first-order decay model does not account for site-specific information such as the availability of electron acceptors. In addition, it does not assume any biodegradation of dissolved constituents in the source zone and assumes biodegradation starts immediately downgradient of the release area. As a result, the predicted dissolved-phase concentrations in the source area are reduced only by non-biodegradation effects (i.e., advection, diffusion, volatilization, etc.). In many cases, the failure of the first-order decay model to consider biodegradation within the source area results in predicted source half-lives up to several orders of magnitude higher than expected based on existing studies of actual petroleum hydrocarbon natural attenuation (Bekins et al. 2002). However, the first-order decay model provides a decent simulation of dissolved-phase hydrocarbon behavior at downgradient locations and can be used to assess the overall migration potential at petroleum release sites. Nevertheless, it should be noted that the first-order decay model is likely to significantly over-estimate the time required for natural attenuation to reduce dissolved-phase hydrocarbon concentrations to regulatory cleanup goals.

The first-order decay model is calibrated by adjusting the first-order decay coefficient until model results agree with known field data. Once calibrated to existing site analytical data, the first-order decay model may be used to predict future plume behavior. First-order decay coefficients determined during model calibration are discussed in Section 4.

3.2.4.2 Instantaneous Reaction Model

Previously conducted dissolved-phase hydrocarbon modeling studies have indicated that the first-order decay model may not be as accurate for simulating natural attenuation processes as the instantaneous reaction model (Conner et al. 1994). Biodegradation of organic contaminants in ground water is more difficult to quantify using a first-order decay equation because electron acceptor limitations are not considered. A more accurate prediction of biodegradation effects may be realized by incorporating the instantaneous reaction equation into a transport model. This approach forms the basis of the BIOSCREEN instantaneous reaction model.

When using the instantaneous reaction model to predict biodegradation of petroleum hydrocarbons, BIOSCREEN operates under the assumption that both aerobic and anaerobic biodegradation processes can be simulated as "instantaneous" reactions which are limited only by the availability of electron acceptors. The microbial reactions are assumed to occur at a much faster rate than the time required for the aquifer to replenish the available electron acceptors.

Therefore, the rates of biodegradation for specific metabolic pathways are assumed to be dependent on the site-specific availability (and re-charge rate) of the corresponding electron acceptors (i.e., oxygen, nitrate, and sulfate) and are not limited by microbial kinetics.

To apply an electron-acceptor-limited kinetic model, such as the instantaneous reaction model, the amount of biodegradation able to be supported by the ground water that moves through the source zone must be estimated. The conceptual instantaneous reaction model used by BIOSCREEN is based on the following assumptions:

- Ground water upgradient of the source is assumed to contain electron acceptors.
- As the upgradient ground water moves through the source zone, petroleum hydrocarbons are released to the ground water from saturated-zone and/or vadose zone soils, resulting in source zone dissolved-phase hydrocarbon concentrations.
- Biodegradation of dissolved-phase petroleum hydrocarbons occurs through both aerobic and anaerobic metabolic pathways until available electron acceptors in the ground water are consumed. Biodegradation is limited by availability of electron acceptors and not by microbial kinetics.
- The total amount of available electron acceptors for biological reactions can be estimated by first calculating the difference between upgradient and source zone electron acceptor concentrations (i.e., oxygen, nitrate, and sulfate) and by measuring the production of metabolic by-products (i.e., ferrous iron and methane) within the source zone.
- Based on the site-specific availability of electron acceptors, utilization factors can be developed to estimate biodegradation rates for corresponding metabolic pathways.

To use the BIOSCREEN instantaneous reaction model, site-specific input parameters are required for delta oxygen, delta nitrate, and delta sulfate (electron acceptor availability), as well as observed ferrous iron and methane concentrations within the source area (to infer electron acceptor availability based on metabolic by-product production). Baseline natural attenuation parameter data were collected at the Old Navy Fuel Farm during August 1996, prior to activation of the biosparging system (i.e., prior to active site remediation of any kind). These data have been used as input parameters for the BTEX/TPH-GRO instantaneous reaction model and are presented in Table 2. To provide a conservative approximation of TPH-DRO biodegradation relative to TPH-GRO biodegradation, the Navy applied a reduction coefficient of 0.3 to the TPH-GRO electron acceptor availability/biodegradation indicator input parameters (i.e., multiplied the TPH-GRO biodegradation indicator parameter concentrations by 0.3 for a 70 percent overall reduction in the corresponding input parameter values). This step was taken to account for the reduced biodegradation rate of TPH-DRO compounds relative to TPH-GRO compounds as well as to account for the competitive degradation requirements of DRO compounds in the presence of GRO compounds. During the model calibration process, site-specific analytical trend data were used to select and support the 0.3 reduction coefficient.

3.2.5 General Model Constraints

BIOSCREEN requires the user to input constraints for the modeled area length and width (ft) and the model simulation time period (years). Specific model constraints for these input parameters for TPH-GRO and TPH-DRO simulations are provided in Table 2.

3.2.6 Source Data

BIOSCREEN requires input parameters for the source zone thickness, source zone width, and corresponding dissolved-phase hydrocarbon concentrations. An input value is also required for the soluble mass remaining in source zone soil which may serve as a continuing source of dissolved-phase hydrocarbon concentrations.

The source zone thickness at petroleum hydrocarbon release sites is typically assumed to correspond to the water table fluctuation or the "smear zone" thickness since petroleum hydrocarbons are lighter than water. A review of field notes and boring logs obtained during the 1999 direct-push investigation indicates that soil contamination at the Old Navy Fuel Farm ranged in thickness from 2 to 6 ft (EA 2000c). The photoionization detector/flame ionization detector field screening data results indicate that soils from 3 to 6 ft below ground surface contained the most elevated concentrations of petroleum hydrocarbons across the site. These findings are consistent with seasonal ground-water elevation fluctuations of 2-3 ft below ground surface. Therefore, the source zone thickness was estimated at 3 ft.

The source zone widths and corresponding dissolved-phase concentrations were taken directly from interpreted dissolved-phase isopleth maps generated from ground-water analytical data.

Table 2 provides detailed source zone input parameter values for the eastern and western plume areas for TPH-GRO and TPH-DRO model simulations.

The input source parameters used for the BIOSCREEN model were consistently selected to provide conservative baseline or "year zero" conditions. In the case of the year zero dissolved-phase TPH-GRO concentration in the eastern source area, a conservative value of 20 mg/L was used since light, non-aqueous phase liquid (LNAPL) had previously been observed in this area.

It should be noted that the Navy has no indication that LNAPL continues to be present at the Old Navy Fuel Farm. The use of baseline dissolved-phase concentration input parameter values, which would otherwise be indicative of potential LNAPL presence, were applied for BIOSCREEN model analyses in an effort to assess the "worst-case" existing condition scenario, consistent with the overall intent of providing a conservative site model for the Old Navy Fuel Farm. There are no current data that would indicate the potential for LNAPL at the Old Navy Fuel Farm. The baseline dissolved-phase concentration input parameters were established solely to ensure that the BIOSCREEN model predictions were as conservative as possible.

As discussed in Section 3.1, the soluble mass, or residual petroleum hydrocarbon mass remaining in source zone soils, was conservatively estimated based on confirmatory soil sampling analytical data collected following the September-November 2000 excavation program (Foster Wheeler 2002). The estimated soluble mass input parameter values are provided in Table 2.

4. MODEL CALIBRATION

When used to predict future plume behavior at sites for which historical analytical data are available, the BIOSCREEN biodegradation models (both first-order decay and instantaneous reaction) must be calibrated so that the model results are consistent with existing temporal and spatial dissolved contaminant data. This section describes the calibration process used for the first-order decay and instantaneous reaction biodegradation models at the Old Navy Fuel Farm to develop predictions of TPH-GRO and TPH-DRO dissolved-phase plume behavior.

4.1 FIRST-ORDER DECAY MODEL CALIBRATION PROCEDURE

Typically, the first-order decay coefficient (λ) is used as a calibration parameter. With this approach, uncertainties in a number of parameters related to biodegradation effects are consolidated into a single calibration parameter. With available historical ground-water analytical data, this calibration procedure provides a direct method for adjusting the BIOSCREEN first-order decay model to known behavior of an existing petroleum hydrocarbon plume by adjusting the input parameters to reflect historical site conditions (i.e., previous source area soil concentration and plume characteristics). Once calibrated, the model may be used to predict future plume behavior based on current site conditions (i.e., residual source area soil concentrations and current plume size and concentration profile).

Prior to model calibration, available site-specific input parameter data are entered and serve as constraints during the calibration process. In cases where site-specific input parameters are not available, typical values (as reported for similar petroleum release sites) are employed. Parameters selected without site-specific data may be varied during the calibration process if adjustment of the first-order decay coefficient is not sufficient to correct the model to existing historical plume data.

As discussed previously, the first-order decay model does not consider biodegradation within the source area and, therefore, tends to significantly over-predict the persistence of dissolved-phase hydrocarbon concentrations. For this reason, the first-order decay model may not be appropriate for simulating the time period required for natural attenuation to mitigate dissolved-phase hydrocarbon concentrations. However, the first-order decay model remains appropriate for providing a conservative prediction of dissolved-phase plume migration potential.

4.2 INSTANTANEOUS REACTION MODEL CALIBRATION

As with the case of the first-order decay model, calibration to actual site conditions is required for use of the instantaneous reaction model. The primary calibration step (if needed) is to adjust the model's dispersivity values. As previously described, values for dispersivity are related to estimated plume length and may vary between 2 and 3 orders of magnitude for a given modeling

scale due to natural variation in hydraulic conductivity at a particular site (Gelhar et al. 1992). Therefore, dispersivity values can be adjusted within a large range and still be within the range of values observed at field test sites.

As a secondary calibration step, the biodegradation capacity calculation may be re-evaluated. There is some judgement involved in averaging the electron acceptor concentrations observed in upgradient monitoring wells; determining the minimum oxygen, nitrate, and sulfate concentrations in the source zone; and estimating the average ferrous iron and methane concentrations in the source zone. Although not needed in most applications, these parameters may be adjusted as a final level of calibration for the instantaneous reaction model.

Since the instantaneous reaction model is calibrated primarily through adjustment of the estimated plume length value, it is necessary to complete calibration procedures for the instantaneous reaction model prior to the first-order decay model so that the calibrated plume length will serve as a fixed-constraint during the first-order decay calibration process.

4.3 CALIBRATION PROCEDURES FOR MODELING HISTORICAL TOTAL PETROLEUM HYDROCARBON-GASOLINE RANGE ORGANIC PLUME BEHAVIOR

At the Old Navy Fuel Farm, historical analytical data (i.e., dissolved-phase BTEX concentrations at the eastern hydrocarbon plume area) were collected during a 6-year period prior to initiation of active site remediation in August 1996. Figures 4 and 6, respectively, provide interpreted dissolved-phase BTEX concentration isopleths for the eastern petroleum hydrocarbon plume developed from ground-water samples collected during April 1990 (O'Brien & Gere 1992) and August 1996 (EA 1997a). As previously discussed, this plume was located in the east-central portion of the Old Navy Fuel Farm and appeared to originate in the vicinity of former JP-5 underground storage tank T-202. This plume previously extended downgradient from the former location of T-202 toward the south-southeast. Since sufficient historical ground-water sampling data are available only for the eastern hydrocarbon release area, this plume will be used for calibration of TPH-GRO simulations for both the eastern and western plume model predictions.

The approximately 6-year period from April 1990 to August 1996 was used for model calibration purposes to represent site-specific natural attenuation conditions for the eastern dissolved-phase BTEX plume at the Old Navy Fuel Farm. As stated previously, several different petroleum releases (with respect to both spill dates and locations within the plume area) may have contributed to the eastern dissolved-phase hydrocarbon plume. For model calibration purposes, the release location was assumed to correspond to the area in the vicinity of former JP-5 storage tank T-202. Since the age of the eastern dissolved-phase plume was not quantifiable, initial conditions were developed based on the April 1990 ground-water sampling event (O'Brien & Gere 1990) and reasonable assumptions for residual soluble petroleum mass in the source area.

Since historical TPH-GRO sampling data were not available, total BTEX was used as a surrogate compound suite for simulating the behavior of TPH-GRO during model calibration. The use of total BTEX as a surrogate suite for simulating TPH-GRO behavior was considered appropriate since BTEX compounds have been found to comprise the majority of dissolved-phase constituents in gasoline and jet fuel dissolved-phase plumes, as described below.

BTEX constituents only comprise a small percentage of the total organic mass in gasoline and jet fuel mixtures. However, the best available information suggests that most gasoline and jet fuel dissolved-phase plumes will be dominated by BTEX components, and that only a small fraction of the plumes contain dissolved-phase non-BTEX compounds. This is due to the BTEX compounds having very high solubilities relative to the remaining fraction of organic mass in these fuel mixtures. In other words, most of the non-BTEX constituents of gasoline and jet fuel are relatively insoluble, creating dissolved-phase plumes that are dominated by the BTEX compounds (Newell and McLeod 1997).

TPH-GRO model calibration results developed based on historical data collected during the period from April 1990 to August 1996 are summarized in Table 3. Hard copies of the BIOSCREEN calibration input parameters and calibration output screens are provided in Appendix A.

As indicated in Table 3, both the first-order decay and instantaneous reaction model predictions are consistent with actual site history with respect to total BTEX plume migration, indicating that migration of the eastern total dissolved-phase BTEX plume remains within 500-700 ft of the interpreted source area. Actual site analytical data collected during August 1996 (EA 1997a) indicated that total dissolved-phase BTEX concentrations were reduced to approximately 1 µg/L at 500 ft from the source area. The first-order reaction model predicted that the maximum total dissolved-phase BTEX concentration at this distance would be 4 µg/L. The instantaneous reaction model predicted that BTEX would not be detectable at this distance by 1996.

As expected, since the instantaneous reaction model considers biodegradation within the source area, the predicted dissolved-phase BTEX concentrations at the source area were less than the corresponding values simulated with the first-order decay model. However, at downgradient locations (i.e., 100-400 ft from the source area), the first-order decay model predicted significantly lower dissolved-phase BTEX concentrations than the corresponding instantaneous reaction model predictions. It should be noted that this trend would have been reversed had the calibration period exceeded 6 years, since the first-order decay model exhibits an asymptotic decay rate of dissolved-phase compounds as the maximum dissolved-phase concentration within the plume source area decreases. As discussed previously, this decay pattern is not consistent with previously conducted biodegradation studies since there would not be a corresponding reduction in available electron acceptors as the source area hydrocarbon concentration decreased. If a longer calibration period had been available for evaluation, the first-order decay model would have significantly over-predicted source area and downgradient dissolved-phase TPH concentrations.

Finally, it should be noted that the instantaneous reaction model provided conservative estimates of the total dissolved-phase BTEX migration potential with respect to actual ground-water analytical data collected during the approximately 6-year calibration period. As a result, BIOSCREEN model predictions based on the instantaneous reaction model (provided in Section 5) should be considered conservative, or worst-case, simulations of future hydrocarbon plume behavior at the Old Navy Fuel Farm.

4.4 CALIBRATION PROCEDURES FOR MODELING HISTORICAL TOTAL PETROLEUM HYDROCARBON-DIESEL RANGE ORGANIC PLUME BEHAVIOR

Insufficient historical analytical data were available to calibrate the BIOSCREEN biodegradation models directly to TPH-DRO dissolved-phase behavior at the Old Navy Fuel Farm. Although a significant number of ground-water sampling events have been conducted during which samples were analyzed for TPH-DRO (i.e., August 1996 – October 2001), the majority of these sampling events were conducted during or immediately following periods of active site remediation, as discussed in Section 2. Therefore, ground-water analytical data were not available to directly calibrate the TPH-DRO simulations to historical periods during which dissolved-phase petroleum mitigation was attributable exclusively to natural attenuation.

However, several site-specific considerations were applied to develop the BIOSCREEN TPH-DRO model constraints. Principal among these considerations was the observation that both the eastern and western dissolved-phase TPH-DRO plumes had migrated approximately 400-500 ft further than the corresponding TPH-GRO plumes, although both hydrocarbon plume types appeared to be sourced from the same or similar locations. Therefore, the TPH-DRO model was calibrated to support the increased migration potential of this hydrocarbon range relative to the lighter, and more readily metabolized, TPH-GRO compounds. Test runs of the calibrated TPH-DRO model, using estimated historical contaminant concentration profiles and residual soluble mass values, supported the current migration extent for this hydrocarbon range.

Secondly, during the biosparging remedial program, it was observed that TPH-GRO range compounds appeared to be more responsive to increased biodegradation potential than corresponding TPH-DRO range compounds. This observation is consistent with information provided from previous natural attenuation and *in situ* biodegradation studies (Wisconsin Department of Natural Resources 1994) and is supported by the chemical structure of the compounds in each fraction (i.e., single ring compounds in TPH-GRO compared to more stable chain ring compounds in TPH-DRO). Therefore, as discussed previously, a biodegradation reduction coefficient was applied to the instantaneous reaction model natural attenuation parameter inputs. A similar reduction of the first-order decay coefficient was applied during the TPH-DRO calibration process.

BIOSCREEN model predictions, based on the calibrated TPH-GRO and TPH-DRO simulations discussed above, are presented in Section 5.

5. MODEL RESULTS

The calibrated TPH-GRO and TPH-DRO BIOSCREEN models were applied to estimates of the current (i.e., as of January 2002) dissolved-phase hydrocarbon plumes and residual source area concentrations depicted on Figures 11 and 12. As previously discussed, the estimated current plume conditions within the Old Navy Fuel Farm fence line were principally based on dissolved-phase analytical data collected during June 1999 (prior to the September-November 2000 remedial soil excavation program). The residual soluble mass estimates for the simulated plume source areas were conservatively developed based on area-weighted averages of the maximum residual soil concentrations reported in confirmatory soil samples collected following remedial excavation. Therefore, the BIOSCREEN models have been developed based on conservative estimates of the current site conditions, with respect to both the dissolved-phase plume and residual soil concentrations.

The following sections discuss the BIOSCREEN model results for TPH-GRO and TPH-DRO dissolved-phase plumes in both the eastern and western areas of the Old Navy Fuel Farm. The BIOSCREEN TPH-GRO and TPH-DRO raw data are provided in Appendixes B and C, respectively.

5.1 TOTAL PETROLEUM HYDROCARBON-GASOLINE RANGE ORGANICS

Figure 11 provides the interpreted current condition of the dissolved-phase TPH-GRO plumes at the Old Navy Fuel Farm. Following calibration procedures, detailed in Section 4, the BIOSCREEN software was used to simulate future dissolved-phase TPH-GRO plume behavior until TPH-GRO concentrations were reduced to <50 µg/L throughout the Old Navy Fuel Farm. Tables 4 and 5 provide the predicted TPH-GRO dissolved-phase concentrations versus distance from the plume source areas from year zero (January 2002) until site closure conditions were achieved. The data provided in Table 4 were developed using the first-order decay model. The data provided in Table 5 were developed using the instantaneous reaction model.

It should be noted that the BIOSCREEN biodegradation model input parameters do not include initial downgradient plume concentrations, for which the degradation time is assumed to be negligible in comparison to source area concentrations. The model allows input of source area and lateral dissolved-phase concentration profiles only. Initial downgradient concentrations are assumed to be zero. Therefore, for cases in which the source area degradation time is less than the time required for the modeled contaminants to migrate to downgradient locations, the BIOSCREEN model cannot be used for predicting downgradient plume concentrations. The instantaneous reaction model applied to simulate biodegradation of petroleum hydrocarbons at the Old Navy Fuel Farm generated results for which downgradient plume concentrations reported as non-detect within a few years of the initial condition period. This was especially true for the TPH-GRO simulations. Data summary Tables 5 and 6 include indications of time periods for which predicted downgradient plume concentrations are considered to be less than actual.

Figures 13 through 16 provide the interpreted dissolved-phase TPH-GRO concentrations based on the first-order decay model for years 5, 10, 20, and 40, respectively. Figures 17 through 20 provide the interpreted dissolved-phase TPH-GRO concentrations based on the instantaneous reaction model for years 5 through 8, respectively.

5.1.1 Eastern Fuel Farm Total Petroleum Hydrocarbon-Gasoline Range Organic Plume

The maximum extents of dissolved-phase TPH-GRO migration at the eastern hydrocarbon plume predicted by the first-order decay and instantaneous reaction models are 500 ft and 300 ft, respectively. These predictions are supported by existing TPH-GRO dissolved-phase analytical data, which indicate that the steady state plume currently extends approximately 350-500 ft downgradient (i.e., southeast) of the interpreted source area. The BIOSCREEN model predictions for maximum migration potential of the eastern TPH-GRO plume are reduced to 200 and 300 ft (first-order decay and instantaneous reaction, respectively) for dissolved-phase concentrations >50 µg/L. Based on the results of the first-order decay and instantaneous reaction models, the eastern dissolved-phase TPH-GRO plume has already reached its maximum migration distance from the source area. Further migration of TPH-GRO compounds to downgradient locations is not expected to occur.

The instantaneous reaction model predicts that the eastern dissolved-phase TPH-GRO plume will be reduced to concentrations <50 µg/L within 11 years (i.e., by 2013).

As expected, since biodegradation within the source area is not considered, the first-order decay model predicts an excessive time period (approximately 1,620 years) for the eastern dissolved-phase TPH-GRO plume to be reduced to concentrations <50 µg/L. This prediction underscores the failure of the first-order decay model to accurately simulate natural attenuation of dissolved-phase hydrocarbons at the source area. Although the first-order decay model results are not considered to be a realistic representation of the time required to meet the overall TPH-GRO cleanup goal, it should be noted that this model, although conservative, predicts no further migration of the eastern TPH-GRO plume.

5.1.2 Western Fuel Farm Total Petroleum-Gasoline Range Organic Plume

The maximum extent of dissolved-phase TPH-GRO migration at the western hydrocarbon plume predicted by the first-order decay model is 400-500 ft. This prediction is supported by existing TPH-GRO dissolved-phase analytical data, which indicate that the steady state plume currently extends approximately 400-500 ft downgradient (i.e., southeast) of the interpreted source area. The maximum extent of dissolved-phase TPH-GRO migration at the western hydrocarbon plume predicted by the instantaneous reaction model is 300 ft. The BIOSCREEN first-order decay and instantaneous model predictions for maximum migration potential of the eastern TPH-GRO plume are reduced to 200-250 ft for dissolved-phase concentrations >50 µg/L. Based on the

results of the first-order decay model, the western dissolved-phase TPH-GRO plume has already reached its maximum migration distance from the source area. Further migration of TPH-GRO compounds to downgradient locations is not expected to occur.

The instantaneous reaction model predicts that the western dissolved-phase TPH-GRO plume will be reduced to concentrations <50 µg/L within 9 years (i.e., by 2011).

As expected, since biodegradation within the source area is not considered, the first-order decay model predicts an excessive time period (approximately 2,405 years) for the western dissolved-phase TPH-GRO plume to be reduced to concentrations <50 µg/L. This prediction underscores the failure of the first-order decay model to accurately simulate natural attenuation of dissolved-phase hydrocarbons at the source area. Although the first-order decay model results are not considered to be a realistic representation of the time required to meet the overall TPH-GRO cleanup goal, it should be noted that this model, although conservative, predicts no further migration of the western TPH-GRO plume.

5.2 TOTAL PETROLEUM HYDROCARBON-DIESEL RANGE ORGANICS

Figure 12 provides the interpreted current condition of the dissolved-phase TPH-DRO plumes at the Old Navy Fuel Farm. Following calibration procedures, detailed in Section 4, the BIOSCREEN software was used to simulate future dissolved-phase TPH-DRO plume behavior until TPH-DRO concentrations were reduced to <50 µg/L throughout the Old Navy Fuel Farm. Tables 6 and 7 provide the predicted TPH-DRO dissolved-phase concentrations versus distance from the plume source areas from year zero (January 2002) until site closure conditions were achieved. The data provided in Table 6 were developed using the instantaneous reaction model. The data provided in Table 7 were developed using the first-order decay model. Figures 21 through 23 provide the interpreted dissolved-phase TPH-DRO concentrations based on the first-order decay model for years 10, 20, and 40, respectively. Figures 24 through 27 provide the interpreted dissolved-phase TPH-DRO concentrations based on the instantaneous reaction model for years 10, 14, 18, and 20, respectively.

5.2.1 Eastern Fuel Farm Total Petroleum Hydrocarbon-Diesel Range Organic Plume

The maximum extents of dissolved-phase TPH-DRO migration at the eastern hydrocarbon plume predicted by the first-order decay and instantaneous reaction models are 800 ft and 500 ft, respectively. These predictions are supported by existing TPH-DRO dissolved-phase analytical data, which indicate that the steady state plume currently extends approximately 500-600 ft downgradient (i.e., southeast) of the interpreted source area. The BIOSCREEN model predictions for maximum migration potential of the eastern TPH-DRO plume are reduced to 400 and 500 ft (first-order decay and instantaneous reaction, respectively) for dissolved-phase concentrations >50 µg/L. Based on the results of the first-order decay and instantaneous reaction

models, the eastern dissolved-phase TPH-DRO plume has already reached its maximum migration distance from the source area. Further migration of TPH-DRO compounds to downgradient locations is not expected to occur.

The instantaneous reaction model predicts that the eastern dissolved-phase TPH-DRO plume will be reduced to concentrations <50 µg/L within 41 years (i.e., by 2043). Within 20 years, the instantaneous reaction model predicts that dissolved-phase TPH-DRO concentrations >50 µg/L will no longer extend beyond the limits of the existing Old Navy Fuel Farm fence line.

As expected, since biodegradation within the source area is not considered, the first-order decay model predicts an excessive time period (>2,740 years) for the eastern dissolved-phase TPH-DRO plume to be reduced to concentrations <50 µg/L. This prediction underscores the failure of the first-order decay model to accurately simulate natural attenuation of dissolved-phase hydrocarbons at the source area. Although the first-order decay model results are not considered to be a realistic representation of the time required to meet the overall TPH-DRO cleanup goal, it should be noted that this model, although conservative, predicts no further migration of the eastern TPH-DRO plume.

5.2.2 Western Fuel Farm Total Petroleum Hydrocarbon-Diesel Range Organic Plume

The maximum extents of dissolved-phase TPH-DRO migration at the western hydrocarbon plume predicted by the first-order decay and instantaneous reaction models are 800 ft. These predictions are supported by existing TPH-DRO dissolved-phase analytical data, which indicate that the steady state plume currently extends approximately 700-800 ft downgradient (i.e., southeast) of the interpreted source area. The BIOSCREEN model predictions for maximum migration potential of the western TPH-DRO plume are reduced to 500 ft (first-order decay model only) for dissolved-phase concentrations >50 µg/L. Based on the results of the first-order decay and instantaneous reaction models, the western dissolved-phase TPH-DRO plume has already reached its maximum migration distance from the source area. Further migration of TPH-DRO compounds to downgradient locations is not expected to occur.

The instantaneous reaction model predicts that the western dissolved-phase TPH-DRO plume will be reduced to concentrations <50 µg/L within 27 years (i.e., by 2029). Within 21 years, the instantaneous reaction model predicts that dissolved-phase TPH-DRO concentrations will no longer extend beyond the limits of the existing Old Navy Fuel Farm fence line.

As expected, since biodegradation within the source area is not considered, the first-order decay model predicts an excessive time period (approximately 1,930 years) for the western dissolved-phase TPH-DRO plume to be reduced to concentrations <50 µg/L. This prediction underscores the failure of the first-order decay model to accurately simulate natural attenuation of dissolved-phase hydrocarbons at the source area. Although the first-order decay model results are not

considered to be a realistic representation of the time required to meet the overall TPH-DRO cleanup goal, it should be noted that this model, although conservative, predicts no further migration of the western TPH-DRO plume.

5.3 MODEL SENSITIVITY ANALYSIS

The BIOSCREEN model results discussed in the previous sections were developed with conservative input parameters that were detailed throughout the text of this report and which are supported by historical analytical trend data collected at the site over a 10-year period. However, in response to several specific technical comments provided by MEDEP requesting an assessment of the effect of altering certain input parameters, the Navy has completed a model sensitivity analysis to evaluate the net change to BIOSCREEN model predictions using alternate input parameters provided by MEDEP.

The model sensitivity analysis was developed by re-running the TPH-GRO and TPH-DRO models for both the eastern and western residual source areas under several different scenarios, including application of the following alternative input parameters:

- Source Zone Thickness: increased from 3 to 5 ft
- Hydraulic Gradient: increased from 0.0073 to 0.01095 ft/ft
- Effective Porosity (n_e): reduced from 0.35 to 0.25.

The BIOSCREEN models prepared for the Old Navy Fuel Farm (i.e., TPH-GRO and TPH-DRO modeling in both the eastern and western residual source areas) were re-run using each of the alternate input parameters alone and all possible combinations with other alternate input parameters. The effects on the predicted contaminant migration range (ft from source areas) and time to hydrocarbon source depletion (years) are summarized in the model sensitivity analysis table provided as Appendix D. Specific effects associated with modification of individual model input parameters are discussed below.

There were no observable changes in the BIOSCREEN model predictions for maximum contaminant migration or years to source depletion as a result of increasing the source zone thickness from 3 to 5 ft. However, it should be noted that the original soluble mass estimate was not alternated with the increased source zone thickness. In other words, the estimated residual soluble mass used for the original BIOSCREEN model (3,600 kg as TPH) was retained and applied over the increased source zone interval used in the model sensitivity analysis. MEDEP has noted that a more conservative assessment would have been provided by increasing the residual soluble mass estimate concurrently with the source zone thickness.

The model sensitivity analysis indicated that increasing the hydraulic gradient from 0.0073 to 0.01095 ft/ft resulted in a reduction of approximately 50 percent in the estimated time to TPH-DRO source depletion. Based on the model sensitivity analysis, the estimated time to source depletion for TPH-DRO ranged from 27 to 41 years for the eastern source area and from 19 to

29 years for the western source area, with the longer time to source depletion estimates associated with the lower hydraulic gradient input parameter value. It is apparent that increasing the hydraulic gradient results in a decreased time for TPH-DRO source depletion as a result of increased contaminant dispersion rate, with an associated increased rate of natural attenuation. A similar effect was noted for the TPH-GRO models, although to a lesser degree since the original time to source depletion estimates was significantly less than corresponding estimates for TPH-DRO range compounds.

Decreasing the effective porosity from 0.35 to 0.25 slightly increased the BIOSCREEN model predictions for maximum contaminant migration (ft) for the western source areas under both the Instantaneous Reaction and First Order Decay models. A slight increase in the predicted migration potential was also noted for the eastern source areas under the First Order Decay models. However, in all cases, the resulting impact to the predicted contaminant migration potential was not significant with respect to the original conclusions for natural attenuation of residual petroleum hydrocarbons at the Old Navy Fuel Farm.

As indicated in the model sensitivity analysis provided in Appendix D, use of the alternate input parameter values resulted in no significant change to the model predictions, other than possibly decreasing the estimated time for residual source depletion. Therefore, the Navy maintains that the original input parameters and associated BIOSCREEN model predictions are valid, defendable, and conservative.

5.4 CONCLUSIONS

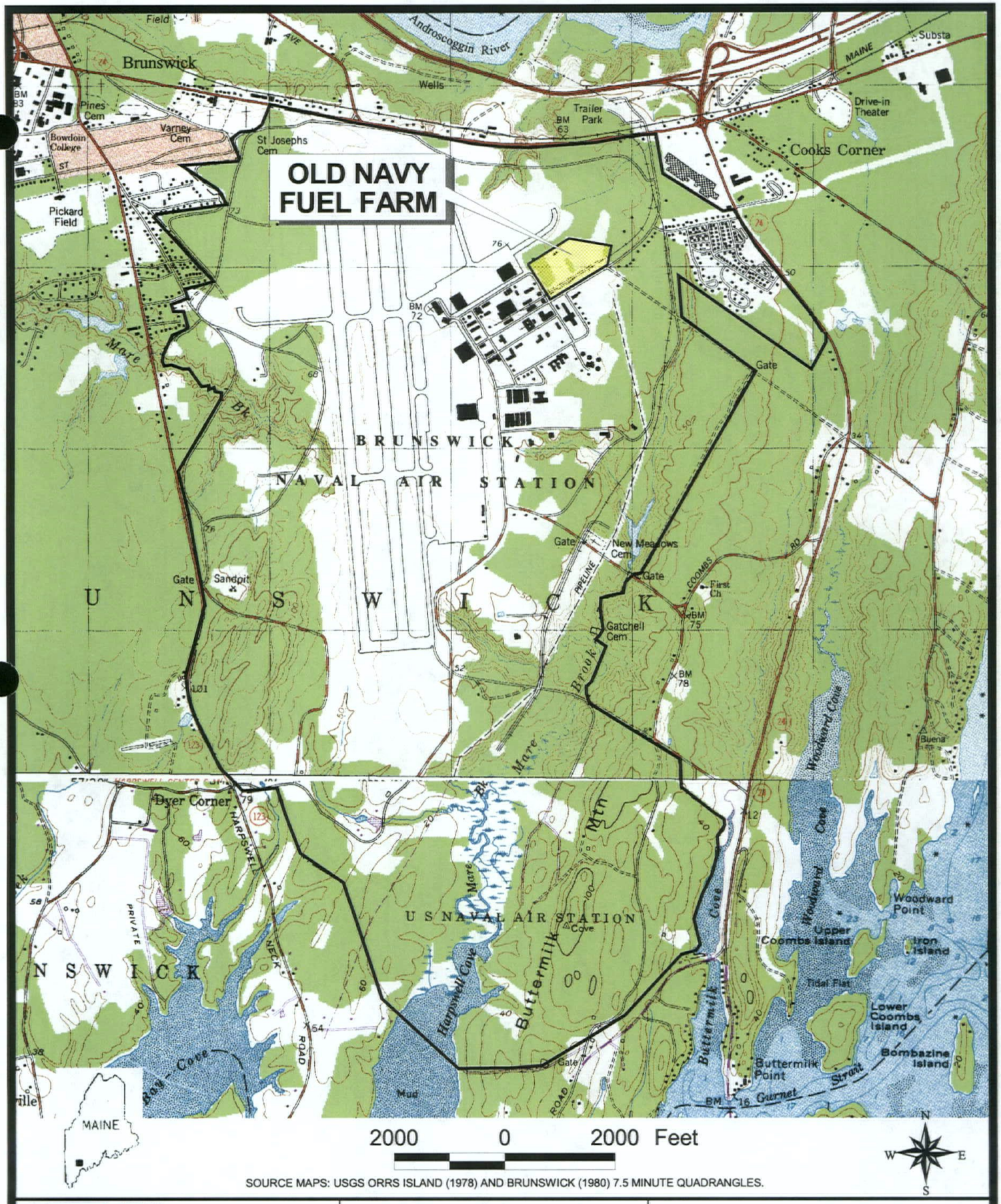
The BIOSCREEN model results discussed in the previous sections were based on conservative assumptions of the current site conditions at the Old Navy Fuel Farm, with respect to both the extent and concentration of the existing dissolved-phase petroleum hydrocarbon plumes as well as the extent and concentration of residual petroleum hydrocarbons remaining in source area soils following remedial soil excavation completed in November 2000. Therefore, the resulting model predictions for the persistence and migration potential of dissolved-phase petroleum hydrocarbons at the Old Navy Fuel Farm should be viewed as a worst-case scenario.

With respect to potential downgradient migration of dissolved-phase petroleum hydrocarbons (i.e., TPH-GRO and TPH-DRO range compounds), both the first-order decay model and the instantaneous reaction model indicate that the existing plumes have reached steady-state conditions and that no further migration of petroleum hydrocarbons is likely to occur. These conclusions are supported by existing ground-water analytical data collected at downgradient sentinel well locations during December 2000 and May and October 2001, that indicate TPH-GRO range compounds are not detected at locations beyond the Old Navy Fuel Farm fence line and that downgradient concentrations of TPH-DRO range compounds are not increasing. Based on both the BIOSCREEN model simulations and existing ground-water analytical data, further migration of dissolved-phase petroleum hydrocarbons is not expected to occur at the Old Navy Fuel Farm.

The BIOSCREEN first-order decay biodegradation model results serve to illustrate the failure of this model to accurately predict the time required for natural attenuation of petroleum hydrocarbons. The conclusion is consistent with previous studies in which the first-order decay model has predicted natural attenuation periods several orders of magnitude greater than observed at typical hydrocarbon release sites (Bekins et al. 2002). Additionally, site-specific natural attenuation data (i.e., electron acceptor demand areas and concentrations of metabolic end products) collected at the Old Navy Fuel Farm indicate that significant biodegradation of petroleum hydrocarbons occurs within the source zones (EA 1997a). Since the first-order decay model does not consider effects of biodegradation within the source area, it was expected that the predicted time period for natural attenuation to reduce petroleum hydrocarbon concentrations would be significantly increased under this model. Therefore, the persistence of dissolved-phase petroleum hydrocarbons at the Old Navy Fuel Farm is considered to be more closely simulated by the BIOSCREEN instantaneous reaction model, as discussed below.

Based on the BIOSCREEN instantaneous reaction model, dissolved-phase TPH-GRO concentrations throughout the Old Navy Fuel Farm will be reduced to 50 µg/L within approximately 11 years (i.e., by 2013). Similarly, dissolved-phase TPH-DRO concentrations throughout the Old Navy Fuel Farm will be reduced to 50 µg/L within approximately 41 years (i.e., by 2043). These natural attenuation periods are based on instantaneous reaction model predictions for the eastern dissolved-phase TPH plume, which was found to be slightly more persistent than the western dissolved-phase TPH plume. Instantaneous reaction model predictions for the western dissolved-phase TPH plume are moderately shorter (i.e., 9 and 27 years to closure for TPH-GRO and TPH-DRO, respectively).

It should be noted that the predicted time periods required for natural attenuation of petroleum hydrocarbons at the Old Navy Fuel Farm are based on conservative estimates of the current site conditions, with respect to both existing dissolved-phase concentrations and residual concentrations of TPH in soil following remedial excavation.



SOURCE MAPS: USGS ORRS ISLAND (1978) AND BRUNSWICK (1980) 7.5 MINUTE QUADRANGLES.

EA ENGINEERING, SCIENCE, AND TECHNOLOGY	OLD NAVY FUEL FARM NAVAL AIR STATION BRUNSWICK, MAINE	FIGURE 1 SITE LOCATION MAP

PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT No	FILE No
ACE	BT	BT	ACE	AS SHOWN	21 SEPT. 2000	29600.35	I:\NASB_GIS \NAVY.APR

LEGEND

MW-NASB-054 — MONITORING WELL LOCATION

MW-NASB-054 — DECOMMISSIONED MONITORING WELL LOCATION

CHAIN LINK FENCE

OLD NAVY FUEL FARM

MW-NASB-213
MW-NASB-096
MW-NASB-062
MW-NASB-063
MW-NASB-051
MW-NASB-044
MW-NASB-045
MW-NASB-205
MW-NASB-211
MW-NASB-061R
MW-NASB-046
MW-NASB-043
MW-NASB-056R
MW-NASB-057
MW-NASB-049
MW-NASB-058
MW-NASB-206
MW-NASB-055
MW-NASB-054
MWR STORAGE SHED
MW-NASB-244
MW-NASB-098
MW-NASB-207
MW-NASB-210
MW-NASB-208
MW-NASB-245
MW-NASB-209R

FIFTH STREET
SIXTH STREET
AVENUE B
FITCH AVENUE
BOARD ROAD
PARKING
3
28
223
13
32
294
150

165' 0 165'

APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\BS_SITEPLAN.DWG

SITE PLAN
OLD NAVY FUEL FARM
NAS BRUNSWICK, MAINE

FIGURE 2

DESIGN	SY
DRAWN	SAP
CHECKED	CJV
PROJECT MANAGER	ACE
DATE	12 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100
ALASKA CALIFORNIA DELAWARE FLORIDA HAWAII MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

LEGEND

MW-NASB-051 (67.10) — MONITORING WELL LOCATION (POTENTIOMETRIC SURFACE ELEVATION, FT MSL)

MW-NASB-054 (68.67) — DECOMMISSIONED MONITORING WELL LOCATION (POTENTIOMETRIC SURFACE ELEVATION, FT MSL)

69 — GROUND-WATER CONTOUR (FT MSL) (DASHED WHERE INFERRED)

INFERRED GROUND-WATER FLOW DIRECTION

CHAIN LINK FENCE

NOTE: MONITORING WELL DECOMMISSIONING COMPLETED DURING 23-30 APRIL 2001.

OLD NAVY FUEL FARM

MW-NASB-213 (69.44)
MW-NASB-096
MW-NASB-062 (71.28)
MW-NASB-063
MW-NASB-044
MW-NASB-045
MW-NASB-211
MW-NASB-051 (67.10)
MW-NASB-205
MW-NASB-061R (70.15)
MW-NASB-043
MW-NASB-046 (65.17)
MW-NASB-049 (61.02)
MW-NASB-056R
MW-NASB-057
MW-NASB-058 (63.60)
MW-NASB-206 (53.41)
MW-NASB-054 (68.67)
MW-NASB-055
MWR STORAGE SHED
MW-NASB-244 (66.33)
MW-NASB-098 (68.83)
MW-NASB-207 (59.93)
MW-NASB-210 (69.55)
MW-NASB-208 (64.82)
MW-NASB-209R (67.49)
MW-NASB-245 (62.39)

FIFTH STREET
SIXTH STREET
FITCH AVENUE
AVENUE B
BOARD ROAD
PARKING

3
28
223
13
294
150

165' 0 165'
APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\BS_GWCONTOUR.DWG

INTERPRETED GROUND-WATER POTENTIOMETRIC SURFACE CONTOUR MAP 11-13 DECEMBER 2000
OLD NAVY FUEL FARM
NAS BRUNSWICK, MAINE

FIGURE 3

DESIGN	SY
DRAWN	SAP
CHECKED	LS
PROJECT MANAGER	ACE

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THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
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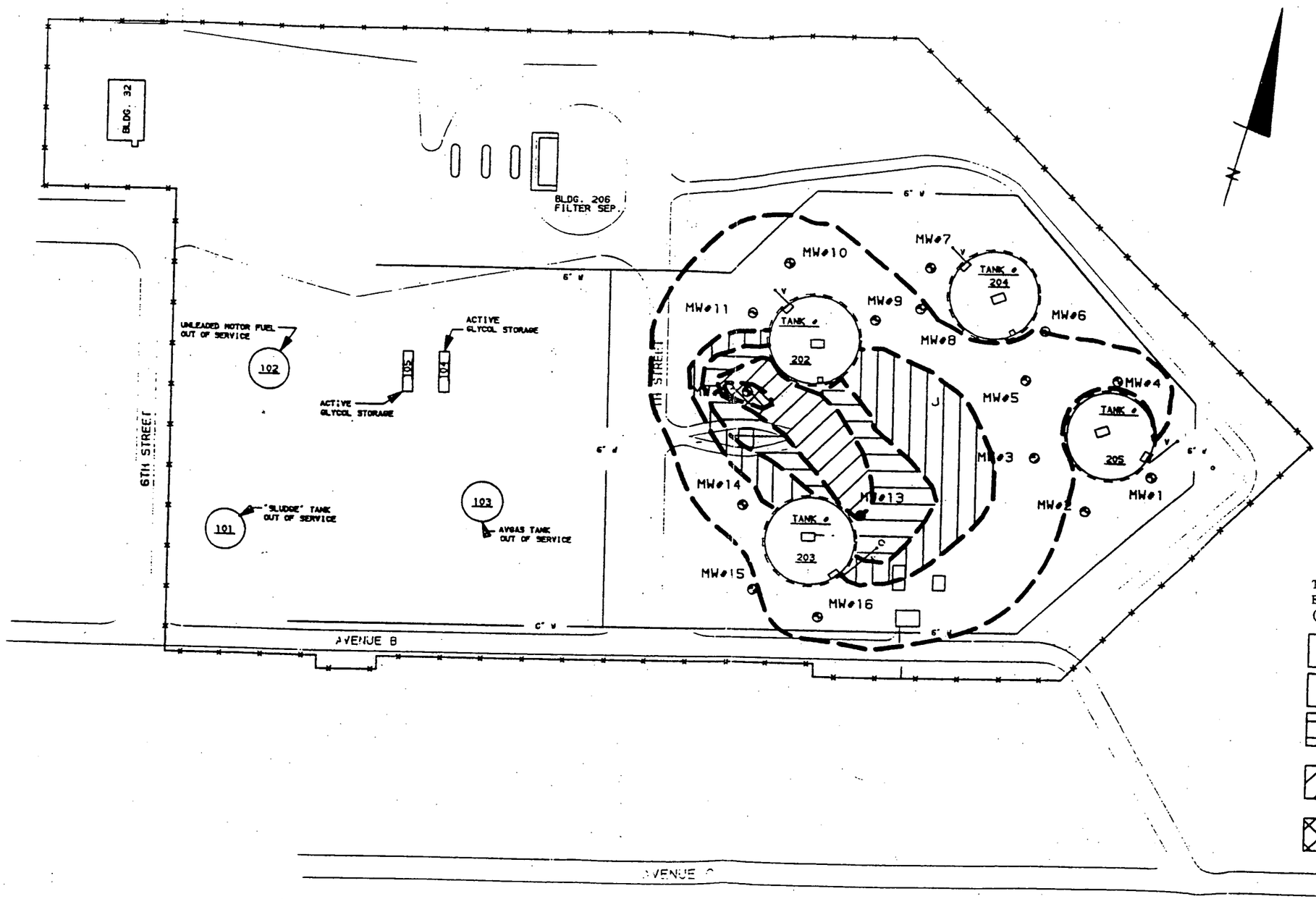
ALASKA CALIFORNIA DELAWARE FLORIDA HAWAII MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

DATE	12 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-



PLAN

LEGEND

MONITORING WELL LOCATION

Total Concentration of Benzene, Ethyl Benzene, Toluene, and Xylene (Parts Per Million)

- 0 TO 5
- 5 TO 10
- 10 TO 15
- 15 TO 20
- OVER 20

NOTE:
ISOCON BOUNDARIES ARE ESTIMATES

1"=23' REDUCED

50 0 50 100

O'BRIEN & GERE

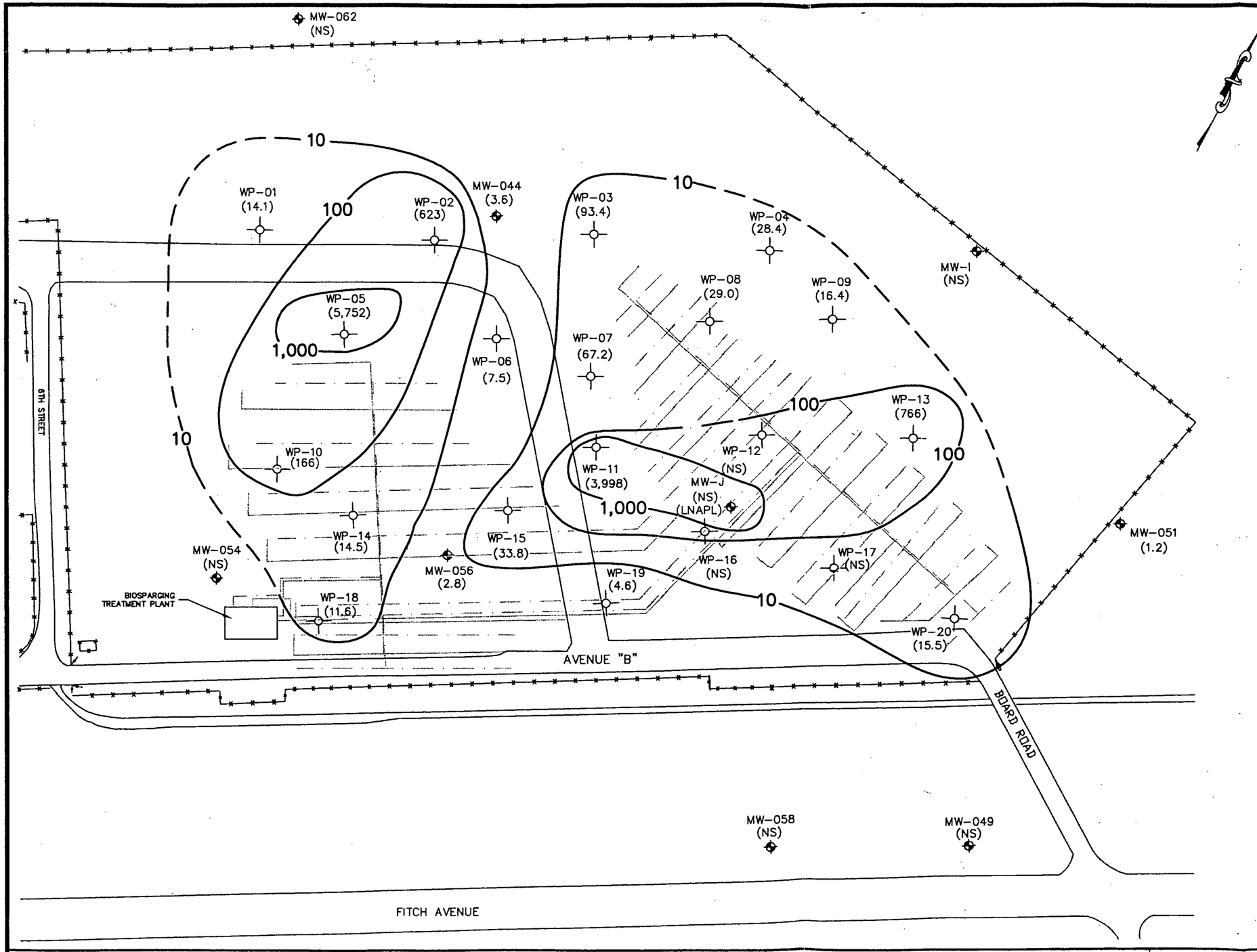
U.S. NAVAL AIR STATION
BRUNSWICK, MAINE

NAVAL - FUEL FARM
ISOCON MAP OF TOTAL BETX
AS DISSOVED IN GROUND WATER
(APRIL 1990)

FILE NO. 1862.020

DATE APRIL. 1990

4



LEGEND

MW-044 (3.6) — MONITORING WELL LOCATION DISSOLVED-PHASE BTEX CONCENTRATION, ug/L NS = LOCATION NOT SAMPLED

WP-01 (14.1) — WELL POINT LOCATION DISSOLVED-PHASE BTEX CONCENTRATION, ug/L NS = LOCATION NOT SAMPLED

CHAIN LINK FENCE

SOIL VAPOR EXTRACTION LINE

AIR SPARGING LINE

10 — INTERPRETED GROUND-WATER DISSOLVED-PHASE BTEX CONCENTRATION ISOPLETH (DASHED WHERE INFERRED)

BTEX INTERPRETED ISOPLETH INTERVAL

10 ug/L
100 ug/L
1,000 ug/L

NOTE:
1. LOCATIONS NOT SAMPLED DUE TO PRESENCE OF LNAPL ASSUMED TO CORRESPOND TO AREAS WITH BTEX CONCENTRATION >1,000 ug/L.
2. LNAPL = LIGHT NON-AQUEOUS PHASE LIQUID.

0 90
APPROXIMATE SCALE (ft)

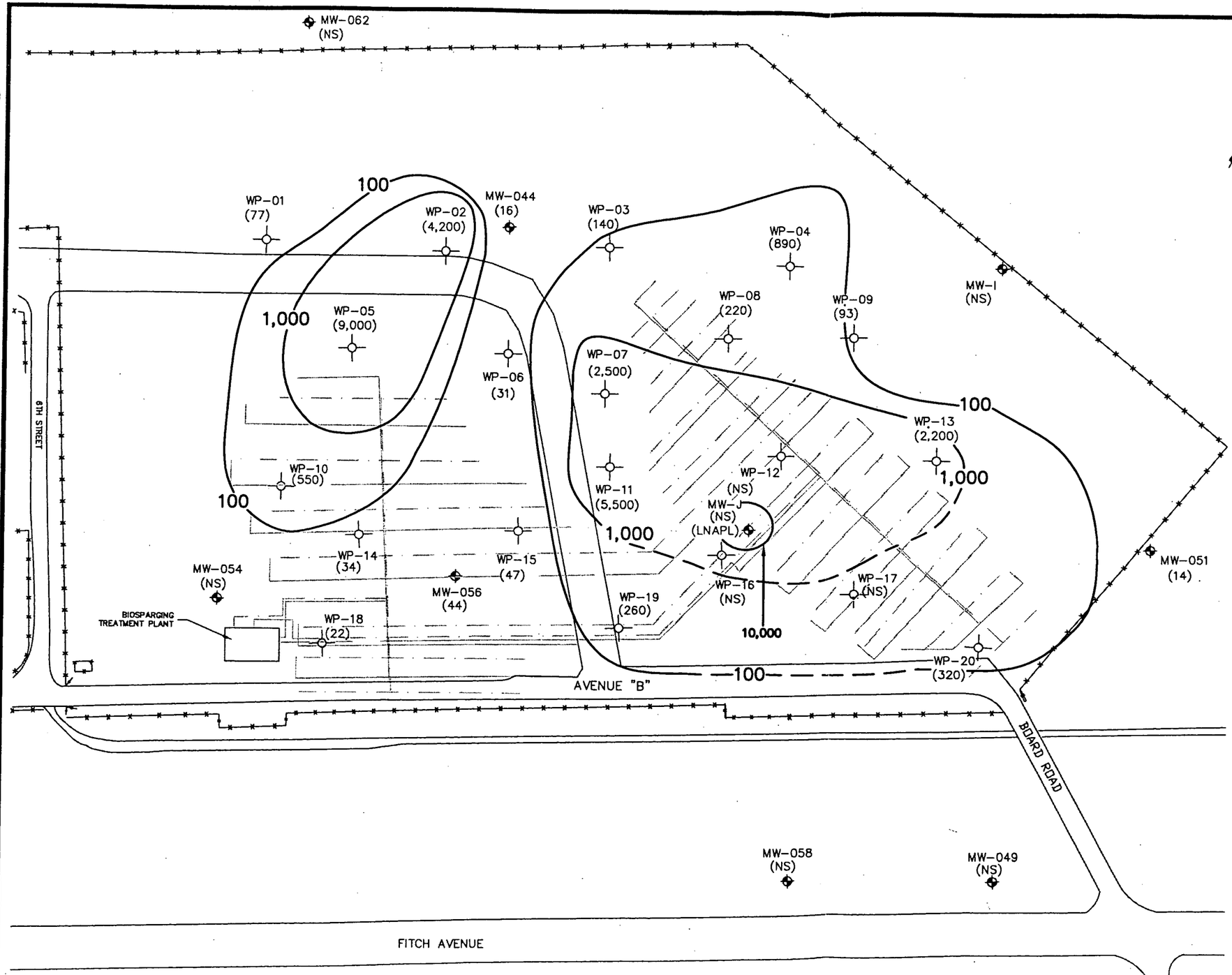
DWG. FILE No. F:\CAD\29600\35\FFAUG.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

OLD NAVY FUEL FARM BIOSPARGING SYSTEM
NAVAL AIR STATION, BRUNSWICK, MAINE

FIGURE 5
INTERPRETED DISSOLVED-PHASE BTEX CONCENTRATION ISOPLETH MAP, GROUND-WATER SAMPLES COLLECTED 7-8 AUGUST 1996

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
SY	SY	02/21/97	29600.35	FFAUG.DWG
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	SHEET NO.
MSB	MSB	AS SHOWN	–	–



LEGEND

- MW-044 (16) — MONITORING WELL LOCATION; DISSOLVED-PHASE TPH-GRO CONCENTRATION, ug/L; NS = LOCATION NOT SAMPLED
- WP-01 (77) — WELL POINT LOCATION; DISSOLVED-PHASE TPH-GRO CONCENTRATION, ug/L; NS = LOCATION NOT SAMPLED
- CHAIN LINK FENCE
- SOIL VAPOR EXTRACTION LINE
- AIR SPARGING LINE
- 100 — INTERPRETED GROUND-WATER DISSOVED-PHASE TPH-GRO CONCENTRATION ISOPLETH (DASHED WHERE INFERRED)

TPH AS GASOLINE RANGE ORGANICS (TPH-GRO) ISOPLETH INTERVAL

100 ug/L
1,000 ug/L
10,000 ug/L

NOTE:
1. LOCATIONS NOT SAMPLED DUE TO PRESENCE OF LNAPL ASSUMED TO CORRESPOND TO AREAS WITH TPH-GRO CONCENTRATION >1,000 ug/L.
2. LNAPL = LIGHT NON-AQUEOUS PHASE LIQUID.

0 90
APPROXIMATE SCALE (ft)

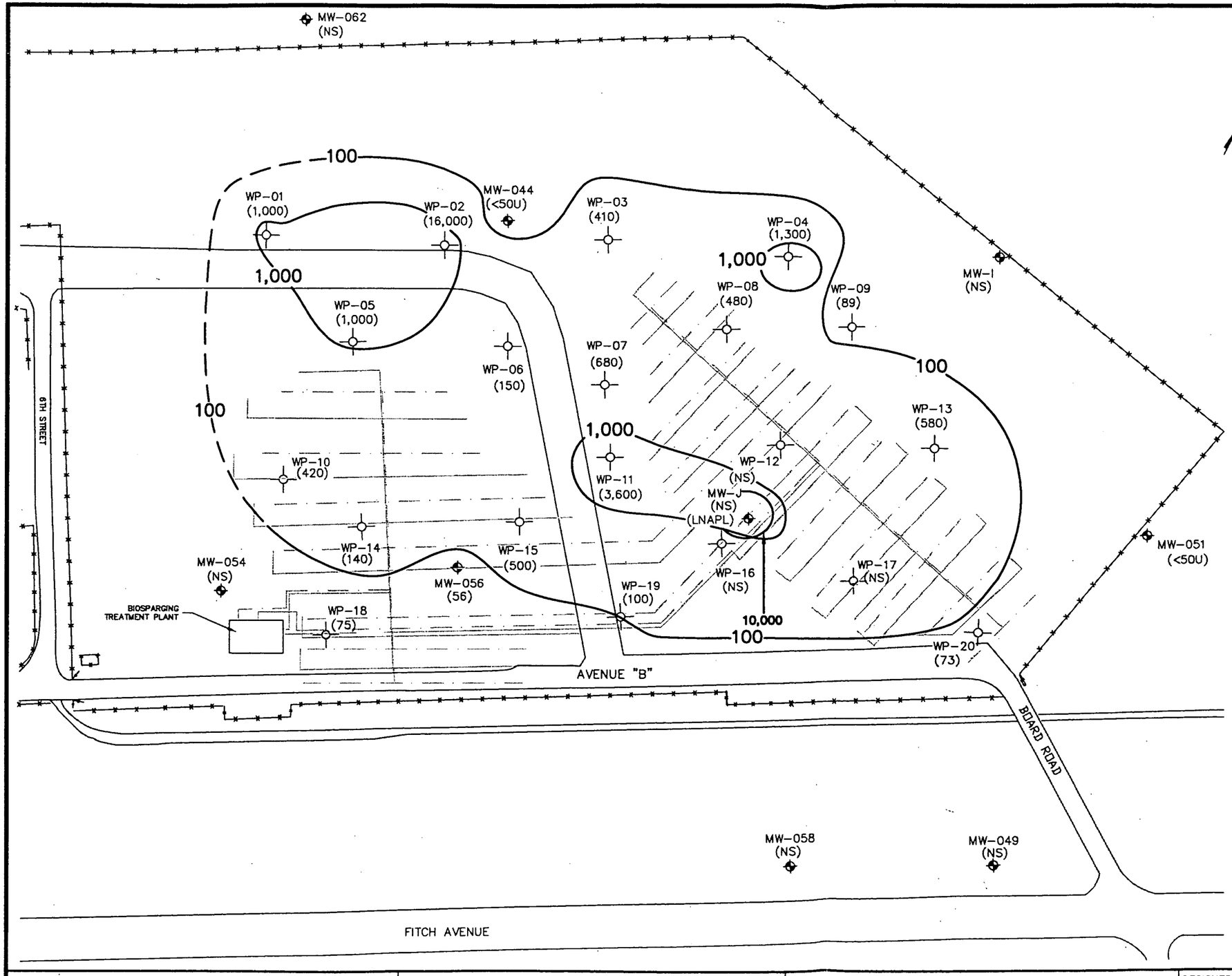
DWG. FILE No. F:\CAD\29600\35\FFAUG.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

OLD NAVY FUEL FARM BIOSPARGING SYSTEM
NAVAL AIR STATION, BRUNSWICK, MAINE

FIGURE 6
INTERPRETED DISSOLVED-PHASE TPH-GRO CONCENTRATION ISOPLETH MAP, GROUND-WATER SAMPLES COLLECTED 7-8 AUGUST 1996

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
SY	SY	02/21/97	29600.35	FFAUG.DWG
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	SHEET NO.
MSB	MSB	AS SHOWN	–	–



LEGEND

MW-044 (<50U)	MONITORING WELL LOCATION DISSOLVED-PHASE TPH-DRO CONCENTRATION, ug/L NS = LOCATION NOT SAMPLED <50U = NOT DETECTED >50 ug/L
WP-01 (1,000)	WELL POINT LOCATION DISSOLVED-PHASE TPH-DRO CONCENTRATION, ug/L NS = LOCATION NOT SAMPLED
	CHAIN LINK FENCE
	SOIL VAPOR EXTRACTION LINE
	AIR SPARGING LINE
100	INTERPRETED GROUND-WATER DISSOVED-PHASE TPH-DRO CONCENTRATION ISOPLETH (DASHED WHERE INFERRED)

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL

100 ug/L
1,000 ug/L

NOTE:
1. LOCATIONS NOT SAMPLED DUE TO PRESENCE OF LNAPL ASSUMED TO CORRESPOND TO AREAS WITH DISSOLVED-PHASE TPH-DRO CONCENTRATION >1,000 ug/L.
2. LNAPL = LIGHT NON-AQUEOUS PHASE LIQUID.

0 90
APPROXIMATE SCALE (ft)

DWG. FILE No. F:\CAD\29600\35\FFAUG.DWG

EA ENGINEERING, SCIENCE, AND TECHNOLOGY

OLD NAVY FUEL FARM BIOSPARGING SYSTEM
NAVAL AIR STATION, BRUNSWICK, MAINE

FIGURE 7
INTERPRETED DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH MAP, SAMPLES COLLECTED 7-8 AUGUST 1996

DESIGNED BY	DRAWN BY	DATE	PROJECT NO.	FILE NAME
SY	SY	02/21/97	29600.35	FFAUG.DWG
CHECKED BY	PROJECT MGR.	SCALE	DRAWING NO.	SHEET NO.
MSB	MSB	AS SHOWN	–	–

LEGEND

MW-NASB-054 — MONITORING WELL LOCATION

MW-NASB-211 — DECOMMISSIONED MONITORING WELL LOCATION

MW-NASB-062 | TPH-GRO (<10U) | TPH-DRO (<50U) — DISSOLVED-PHASE TPH-GRO AND TPH-DRO CONCENTRATIONS

U=NOT DETECTED. SAMPLE QUANTITATION LIMIT SHOWN AS <__U

TPH-GRO=TOTAL PETROLEUM HYDROCARBONS GASOLINE RANGE ORGANICS

TPH-DRO=TOTAL PETROLEUM HYDROCARBONS DIESEL RANGE ORGANICS

J=REPORTED BELOW DETECTED LIMIT

CHAIN LINK FENCE

OLD NAVY FUEL FARM

MW-NASB-096 (NS)

MW-NASB-213 | TPH-GRO (<10U) | TPH-DRO (<50U)

MW-NASB-062 | TPH-GRO (<10U) | TPH-DRO (<50U)

MW-NASB-063 (NS)

MW-NASB-044

MW-NASB-045

MW-NASB-211

MW-NASB-051 | TPH-GRO (<10U) | TPH-DRO 51

MW-NASB-205 (NS)

MW-NASB-061R | TPH-GRO 24 | TPH-DRO 700

MW-NASB-043

MW-NASB-046 (NS)

MW-NASB-056R

MW-NASB-057

MW-NASB-049 | TPH-GRO (<10U) | TPH-DRO 87

MW-NASB-058 | TPH-GRO (<10U) | TPH-DRO 54

MW-NASB-206 | TPH-GRO (<10U) | TPH-DRO (<50U)

MW-NASB-055

MW-NASB-054 | TPH-GRO 45 | TPH-DRO 190

MW-NASB-244 | TPH-GRO (<10U) | TPH-DRO 43J

MW-NASB-098 | TPH-GRO (<10U) | TPH-DRO 130

MW-NASB-207 | TPH-GRO (<10U) | TPH-DRO 62

MW-NASB-210 | TPH-GRO (<10U) | TPH-DRO 100

MW-NASB-208 | TPH-GRO (<10U) | TPH-DRO 250

MW-NASB-209R | TPH-GRO (<10U) | TPH-DRO 44J

MW-NASB-245 (NS)

FIFTH STREET

SIXTH STREET

AVENUE B

FITCH AVENUE

BOARD ROAD

PARKING

3

28

223

13

294

150

165' 0 165'

APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\DEC00_TAGMAP.DWG

DISSOLVED-PHASE TPH-GRO AND TPH-DRO DETECTED IN GROUND-WATER SAMPLES COLLECTED DURING DECEMBER 2000

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 8

DESIGN	CJV
DRAWN	CJV
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100

ALASKA, CALIFORNIA, DELAWARE, FLORIDA, HAWAII, MARYLAND, MASSACHUSETTS, NEBRASKA, NEW JERSEY, NEW YORK, OREGON, PENNSYLVANIA, RHODE ISLAND, TENNESSEE, TEXAS, WASHINGTON

DATE	18 FEBRUARY 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-

LEGEND

MW-NASB-054 — MONITORING WELL LOCATION

MW-NASB-211 — DECOMMISSIONED MONITORING WELL LOCATION

MW-NASB-208

TPH-GRO	(<10U)
TPH-DRO	410

DISSOLVED-PHASE TPH-GRO AND TPH-DRO CONCENTRATIONS

U=NOT DETECTED. SAMPLE QUANTITATION LIMIT SHOWN AS <___U

TPH-GRO=TOTAL PETROLEUM HYDROCARBONS GASOLINE RANGE ORGANICS

TPH-DRO=TOTAL PETROLEUM HYDROCARBONS DIESEL RANGE ORGANICS

J=REPORTED BELOW DETECTED LIMIT

CHAIN LINK FENCE

OLD NAVY FUEL FARM

MW-NASB-096 (NS)

MW-NASB-213

MW-NASB-063 (NS)

MW-NASB-062 (NS)

MW-NASB-044

MW-NASB-045

MW-NASB-051 (NS)

MW-NASB-211

MW-NASB-205 (NS)

MW-NASB-061R

MW-NASB-043

MW-NASB-046

TPH-GRO	(<10U)
TPH-DRO	43J

MW-NASB-056R

MW-NASB-057

MW-NASB-049

TPH-GRO	(<10U)
TPH-DRO	63J

MW-NASB-055

MW-NASB-211

MW-NASB-058

TPH-GRO	(<10U)
TPH-DRO	26J

MW-NASB-206

TPH-GRO	(<10U)
TPH-DRO	22J

MW-NASB-244

TPH-GRO	(<10U)
TPH-DRO	24J

MW-NASB-098

TPH-GRO	(<10U)
TPH-DRO	91

MW-NASB-207

TPH-GRO	(<10U)
TPH-DRO	44J

MW-NASB-210

TPH-GRO	(<10U)
TPH-DRO	200

MW-NASB-208

TPH-GRO	(<10U)
TPH-DRO	400

MW-NASB-209R

TPH-GRO	(<10U)
TPH-DRO	43J

MW-NASB-245 (NS)

FIFTH STREET

SIXTH STREET

AVENUE B

BOARD ROAD

FITCH AVENUE

PARKING

3

28

223

13

294

150

32

165' 0 165'

APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\000\NAVY\2960035\CAD\FFBIOSCREEN\MAY01_TAGMAP.DWG

DISSOLVED-PHASE TPH-GRO AND TPH-DRO DETECTED IN GROUND-WATER SAMPLES COLLECTED DURING MAY 2001

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 9

DESIGN	CJV
DRAWN	CJV
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100

ALASKA CALIFORNIA DELAWARE FLORIDA MAINE MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

DATE	18 FEBRUARY 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-

LEGEND

MW-NASB-054 — MONITORING WELL LOCATION

MW-NASB-211 — DECOMMISSIONED MONITORING WELL LOCATION

MW-NASB-244

TPH-GRO	(<50U)
TPH-DRO	55J

DISSOLVED-PHASE TPH-GRO AND TPH-DRO CONCENTRATIONS

U=NOT DETECTED. SAMPLE QUANTITATION LIMIT SHOWN AS <___U

TPH-GRO=TOTAL PETROLEUM HYDROCARBONS GASOLINE RANGE ORGANICS

TPH-DRO=TOTAL PETROLEUM HYDROCARBONS DIESEL RANGE ORGANICS

J=REPORTED BELOW DETECTED LIMIT

CHAIN LINK FENCE

OLD NAVY FUEL FARM

MW-NASB-096 (NS)

MW-NASB-213

MW-NASB-062

TPH-GRO	(<50U)
TPH-DRO	(<30U)

MW-NASB-063 (NS)

MW-NASB-044

MW-NASB-045

MW-NASB-051

TPH-GRO	(<50U)
TPH-DRO	(<30U)

MW-NASB-205 (NS)

MW-NASB-211

MW-NASB-061R

MW-NASB-043

MW-NASB-046

TPH-GRO	(<50U)
TPH-DRO	86J

BOARD ROAD

MW-NASB-056R

MW-NASB-057

MW-NASB-049

TPH-GRO	(<50U)
TPH-DRO	58J

SIXTH STREET

FIFTH STREET

AVENUE B

MW-NASB-055

MW-NASB-211

MW-NASB-058

TPH-GRO	(<50U)
TPH-DRO	34J

FITCH AVENUE

MW-NASB-206

TPH-GRO	(<50U)
TPH-DRO	(<30U)

MW-NASB-244

TPH-GRO	(<50U)
TPH-DRO	55J

PARKING

MW-NASB-098

TPH-GRO	(<50U)
TPH-DRO	(<30U)

MW-NASB-207

TPH-GRO	(<50U)
TPH-DRO	64J

MW-NASB-210

TPH-GRO	(<50U)
TPH-DRO	60J

PARKING

MW-NASB-208 (NS)

MW-NASB-209R

TPH-GRO	(<50U)
TPH-DRO	48J

MW-NASB-245

TPH-GRO	(<50U)
TPH-DRO	117

PARKING

3

28

223

13

294

150

165' 0 165'

APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\OCT01_TAGMAP.DWG

DISSOLVED-PHASE TPH-GRO AND TPH-DRO DETECTED IN GROUND-WATER SAMPLES COLLECTED DURING OCTOBER 2001

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 10

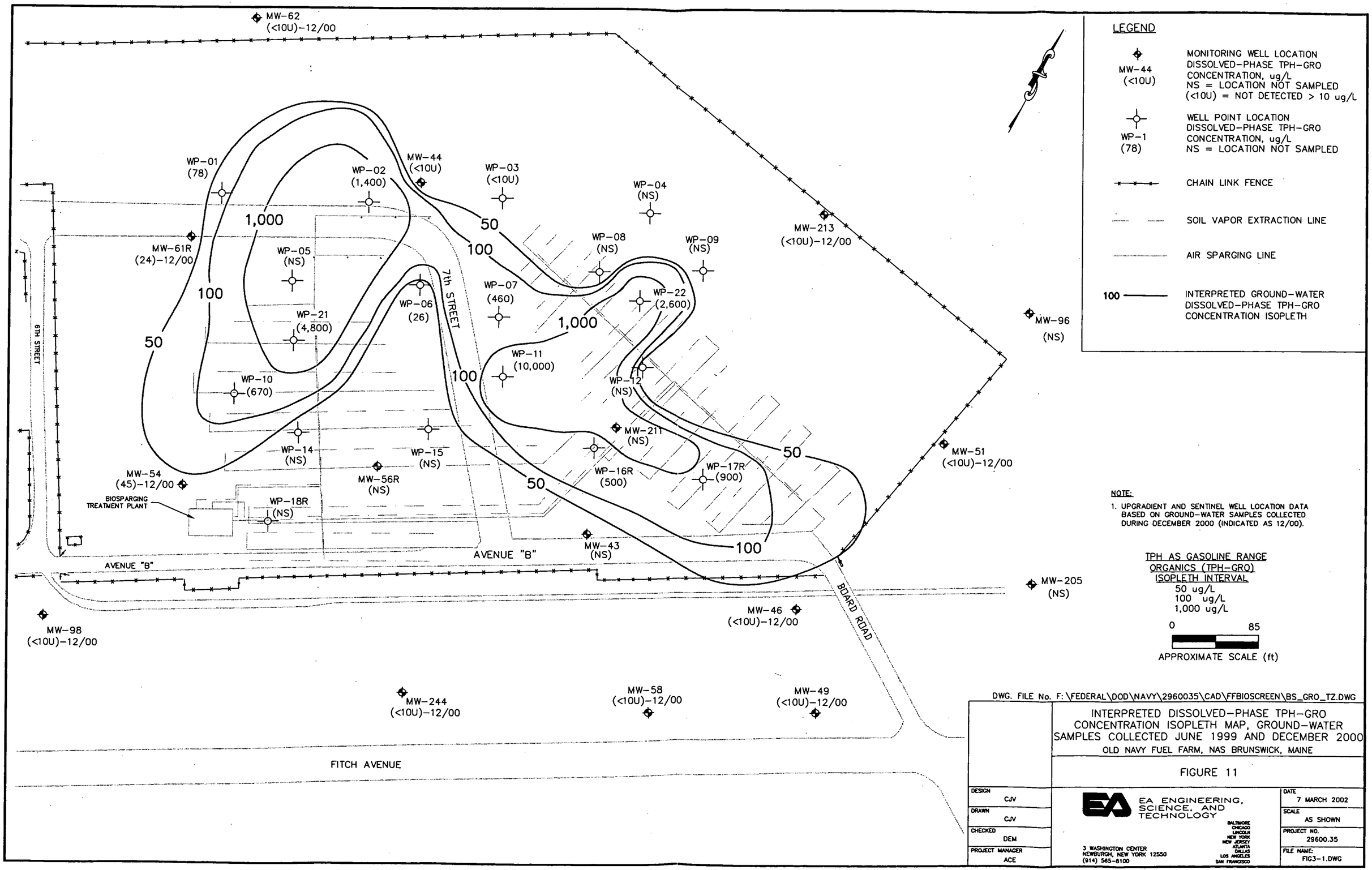
DESIGN	CJV
DRAWN	CJV
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.

THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100

ALASKA CALIFORNIA DELAWARE FLORIDA MAINE MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

DATE	18 FEBRUARY 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-



DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600035\CAD\FFBIOSCREEN\BS_GRO_TZ.DWG

INTERPRETED DISSOLVED-PHASE TPH-GRO CONCENTRATION ISOPLETH MAP, GROUND-WATER SAMPLES COLLECTED JUNE 1999 AND DECEMBER 2000

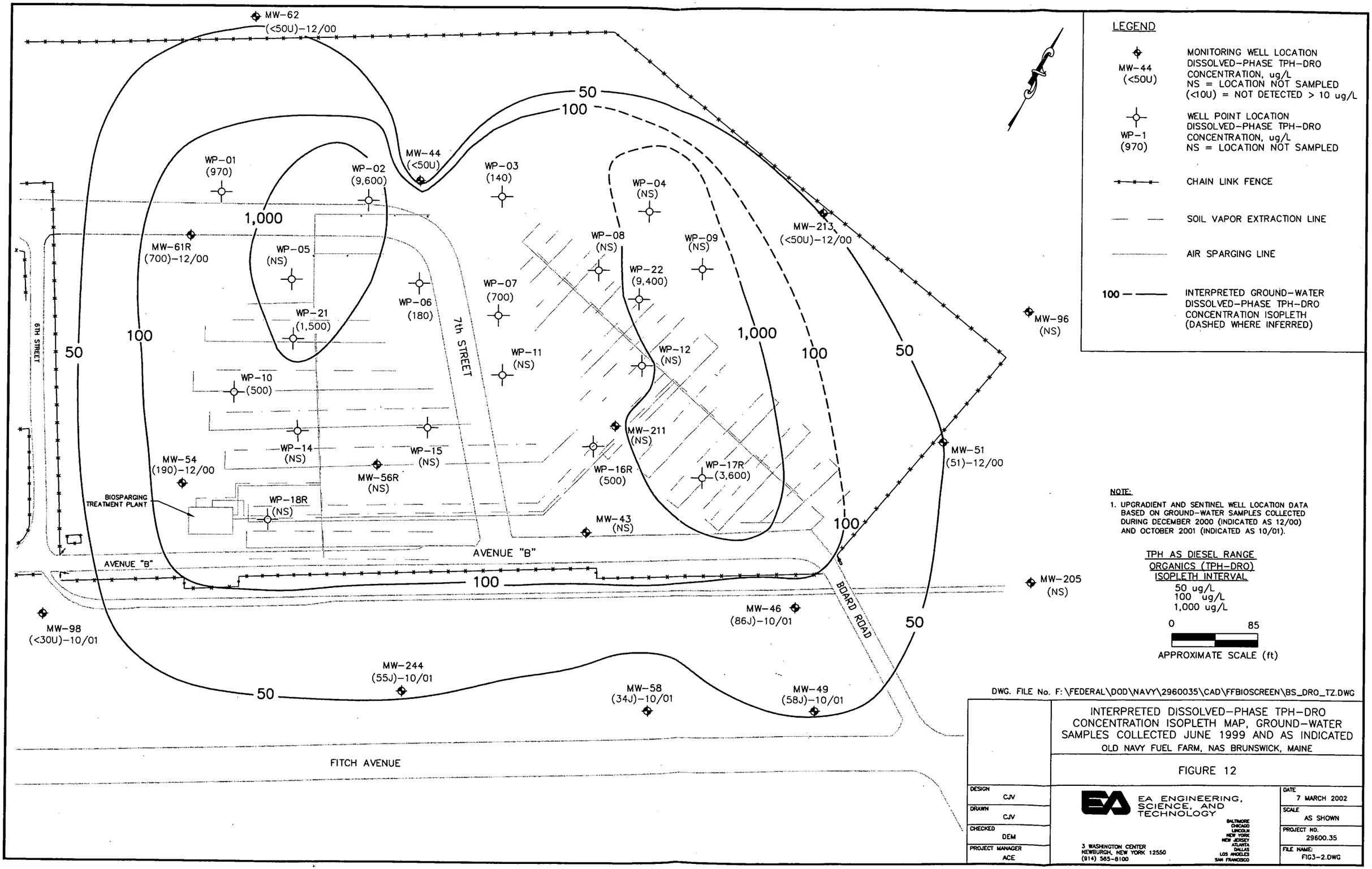
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 11

DESIGN	CJV
DRAWN	CJV
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
BALTIMORE CHICAGO LINCOLN NEW YORK NEW JERSEY ATLANTA DALLAS LOS ANGELES SAN FRANCISCO
3 WASHINGTON CENTER
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG3-1.DWG



LEGEND

- MW-44 (<50U): MONITORING WELL LOCATION
  DISSOLVED-PHASE TPH-DRO CONCENTRATION, ug/L
  NS = LOCATION NOT SAMPLED
  (<10U) = NOT DETECTED > 10 ug/L
- WP-1 (970): WELL POINT LOCATION
  DISSOLVED-PHASE TPH-DRO CONCENTRATION, ug/L
  NS = LOCATION NOT SAMPLED
- CHAIN LINK FENCE
- SOIL VAPOR EXTRACTION LINE
- AIR SPARGING LINE
- 100 — INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH (DASHED WHERE INFERRED)

NOTE:

1. UPGRADIENT AND SENTINEL WELL LOCATION DATA BASED ON GROUND-WATER SAMPLES COLLECTED DURING DECEMBER 2000 (INDICATED AS 12/00) AND OCTOBER 2001 (INDICATED AS 10/01).

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

0 85

APPROXIMATE SCALE (ft)

DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\BS_DRO_TZ.DWG

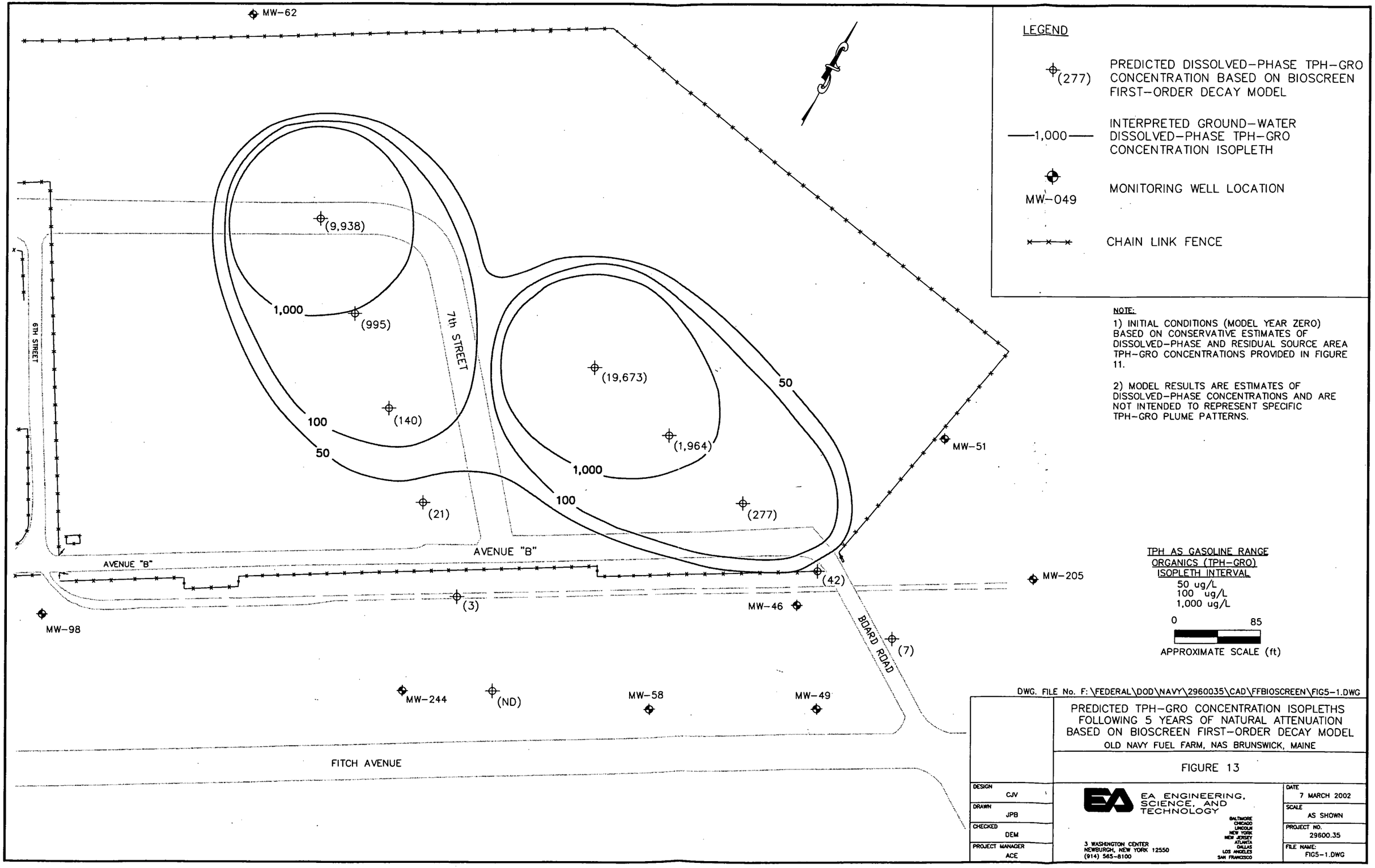
INTERPRETED DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH MAP, GROUND-WATER SAMPLES COLLECTED JUNE 1999 AND AS INDICATED
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 12

DESIGN	CJV
DRAWN	CJV
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
BALTIMORE CHICAGO LINCOLN NEW YORK NEW JERSEY ATLANTA DALLAS LOS ANGELES SAN FRANCISCO
3 WASHINGTON CENTER
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG3-2.DWG



DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\FIG5-1.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 5 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL

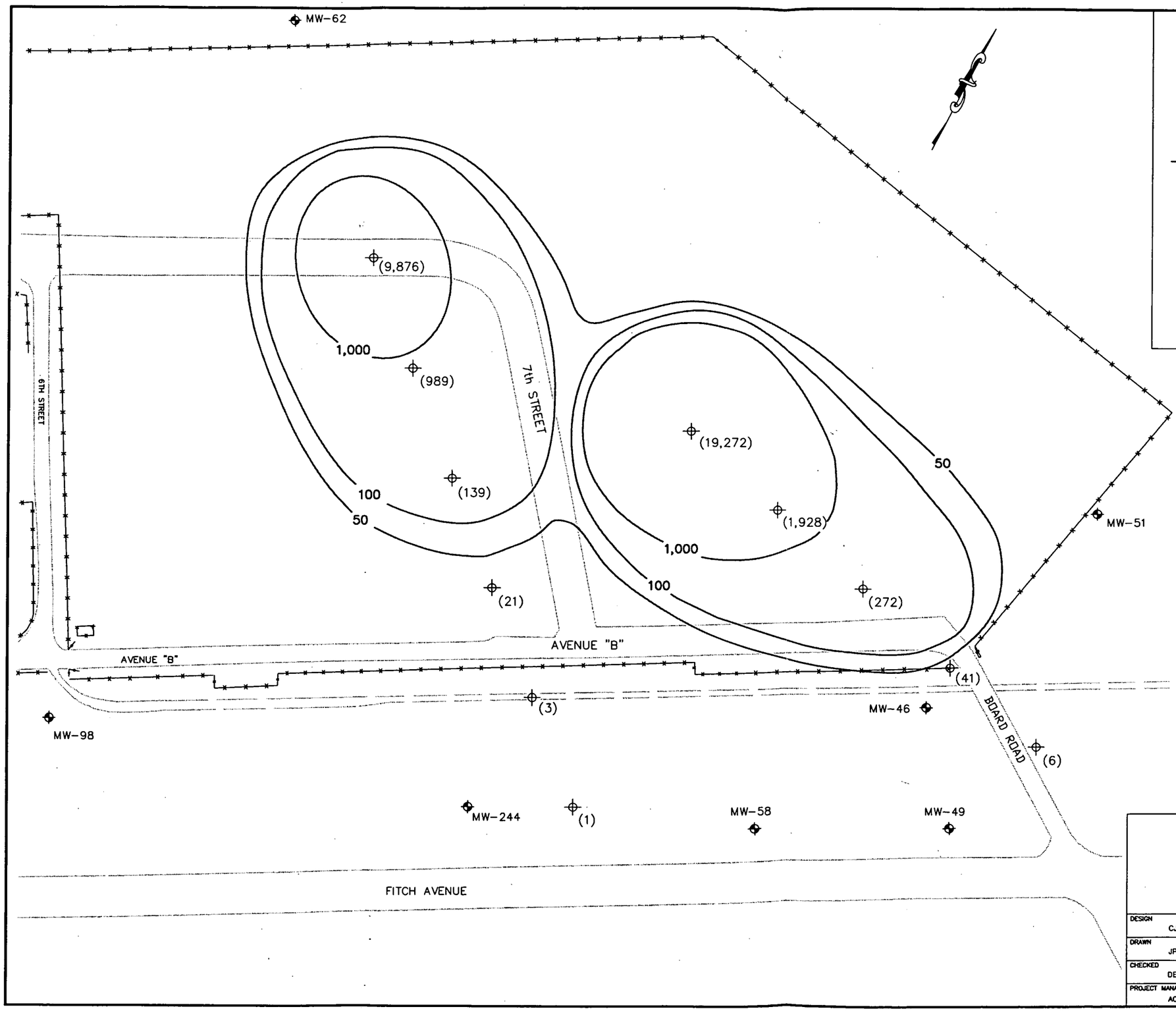
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 13

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
BALTIMORE CHICAGO LINCOLN NEW YORK NEW JERSEY ATLANTA DALLAS LOS ANGELES SAN FRANCISCO
3 WASHINGTON CENTER
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-1.DWG



LEGEND

(272) PREDICTED DISSOLVED-PHASE TPH-GRO CONCENTRATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL

—1,000— INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-GRO CONCENTRATION ISOPLETH

MW-049 MONITORING WELL LOCATION

CHAIN LINK FENCE

NOTE:

1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-GRO CONCENTRATIONS PROVIDED IN FIGURE 11.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-GRO PLUME PATTERNS.

TPH AS GASOLINE RANGE ORGANICS (TPH-GRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

0 85
APPROXIMATE SCALE (ft)

DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\FIG5-2.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 10 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 14

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

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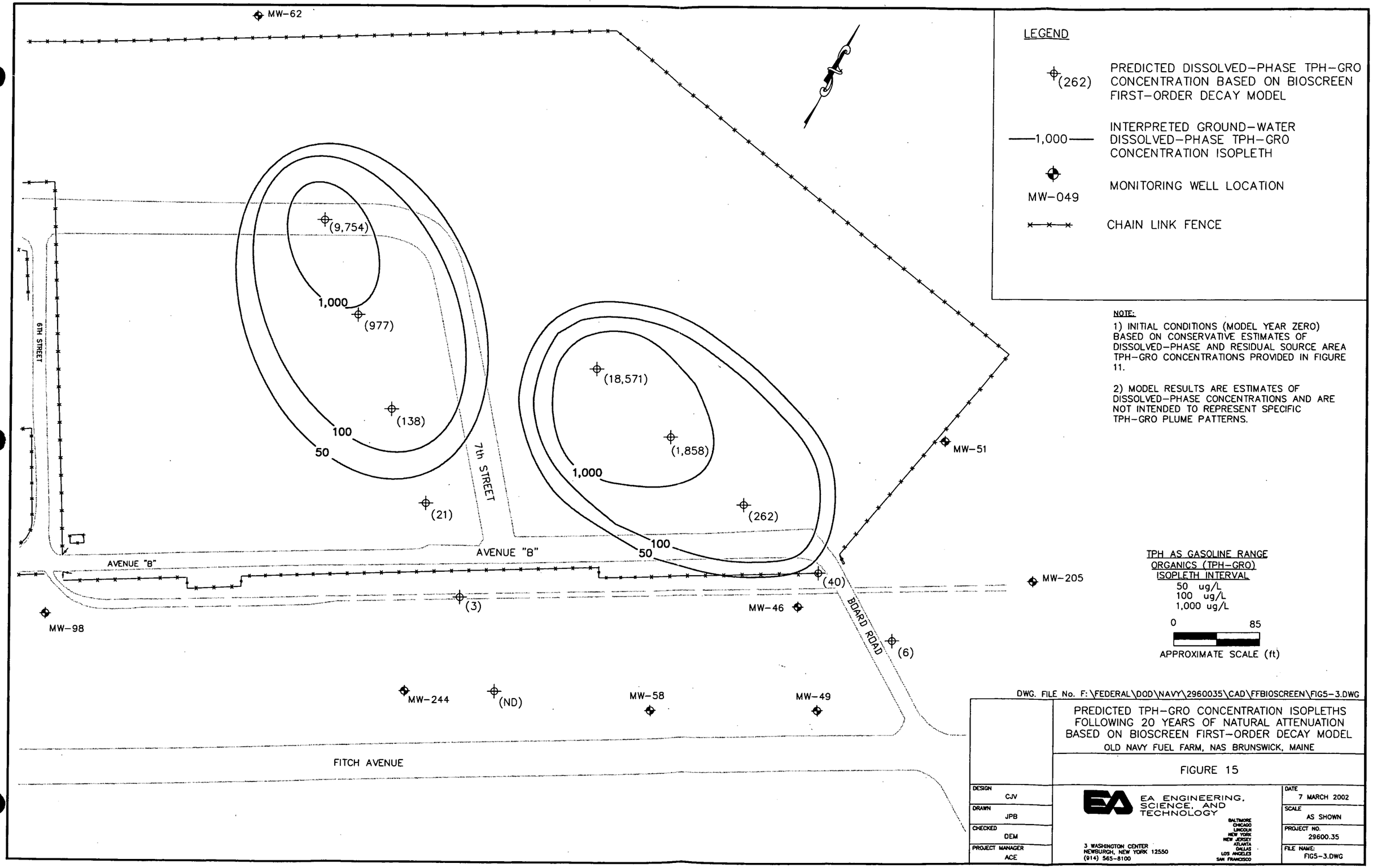
BALTIMORE CHICAGO LINCOLN NEW YORK NEW JERSEY ATLANTA DALLAS LOS ANGELES SAN FRANCISCO
3 WASHINGTON CENTER
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-2.DWG



DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600035\CAD\FFBIOSCREEN\FIG5-3.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 20 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL

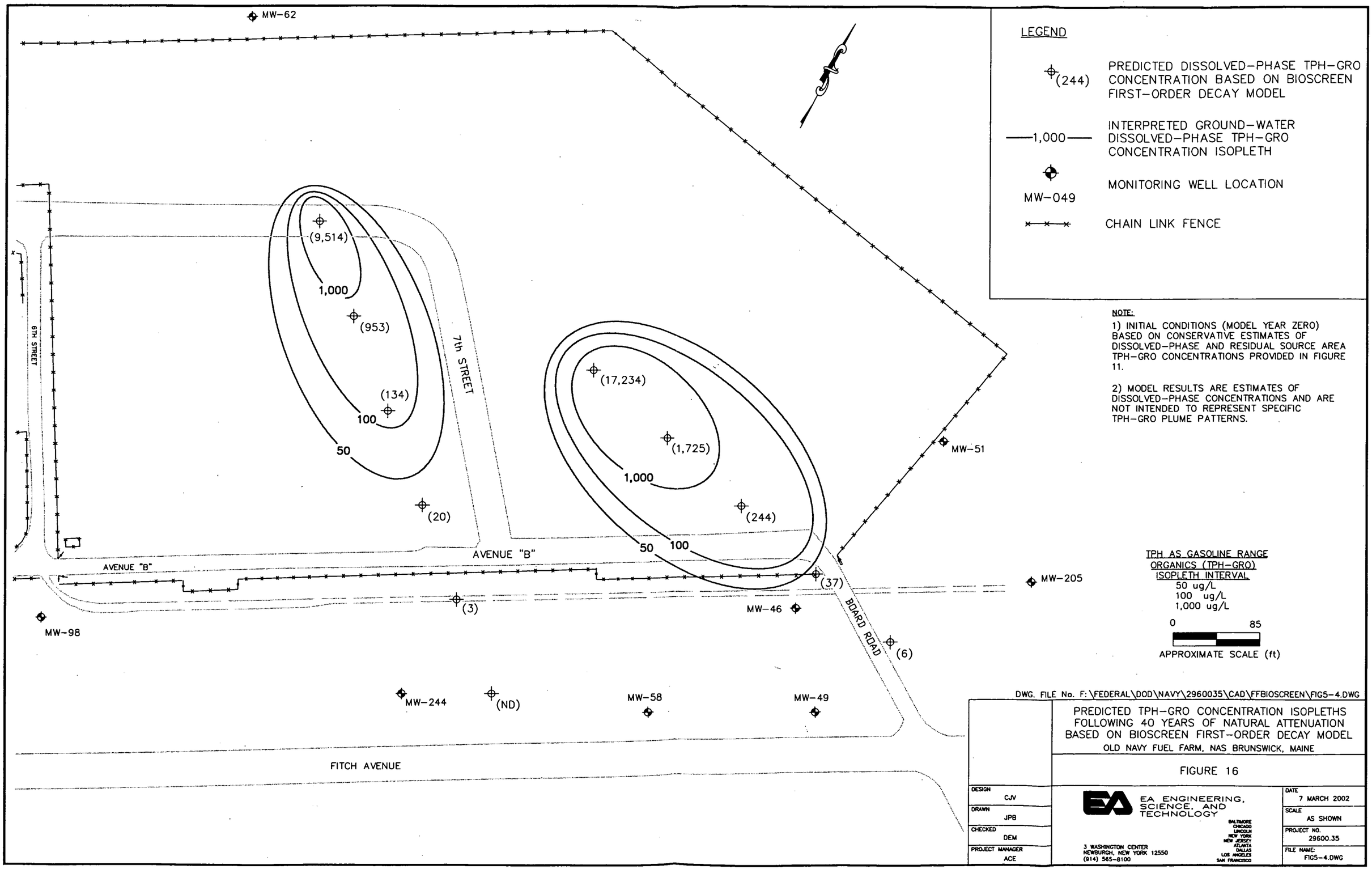
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 15

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
BALTIMORE CHICAGO LINCOLN NEW YORK NEW JERSEY ATLANTA DALLAS LOS ANGELES SAN FRANCISCO
3 WASHINGTON CENTER
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-3.DWG



DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600035\CAD\FFBIOSCREEN\FIG5-4.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 40 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 16

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

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BALTIMORE CHICAGO LINCOLN NEW YORK NEW JERSEY ATLANTA DALLAS LOS ANGELES SAN FRANCISCO
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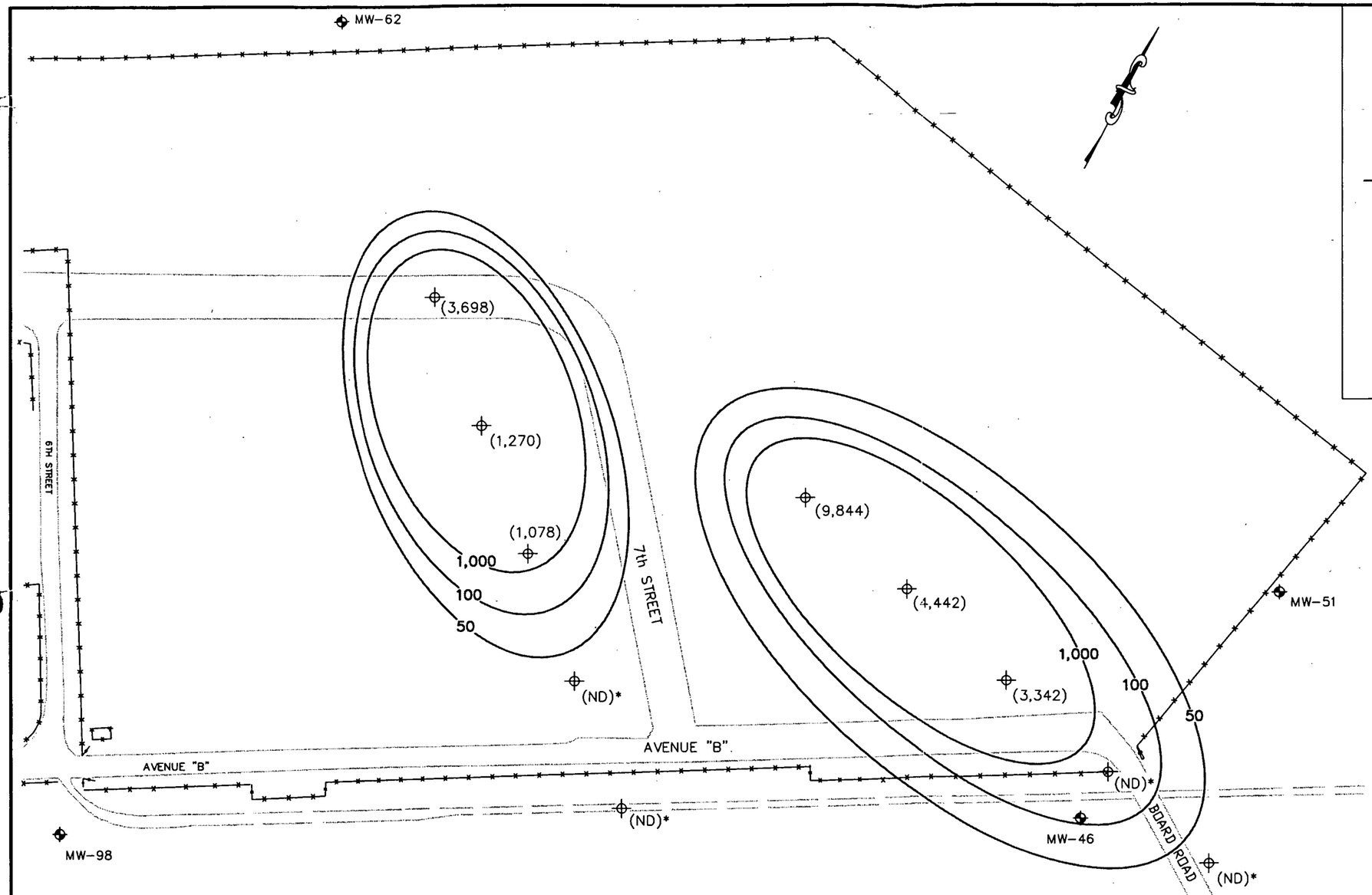
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-4.DWG



LEGEND

(3,342)	PREDICTED DISSOLVED-PHASE TPH-GRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL
1,000	INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-GRO CONCENTRATION ISOPLETH
MW-049	MONITORING WELL LOCATION
	CHAIN LINK FENCE
(ND)*	SIMULATED DATA NOT AVAILABLE, BIOSCREEN MODEL ASSUMES INITIAL DOWNGRADIENT CONCENTRATION = 0.0.

NOTE:

1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-GRO CONCENTRATIONS PROVIDED IN FIGURE 11.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-GRO PLUME PATTERNS.

TPH AS GASOLINE RANGE ORGANICS (TPH-GRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

0 85
APPROXIMATE SCALE (ft)

DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\FIG5-5.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 5 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 17

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

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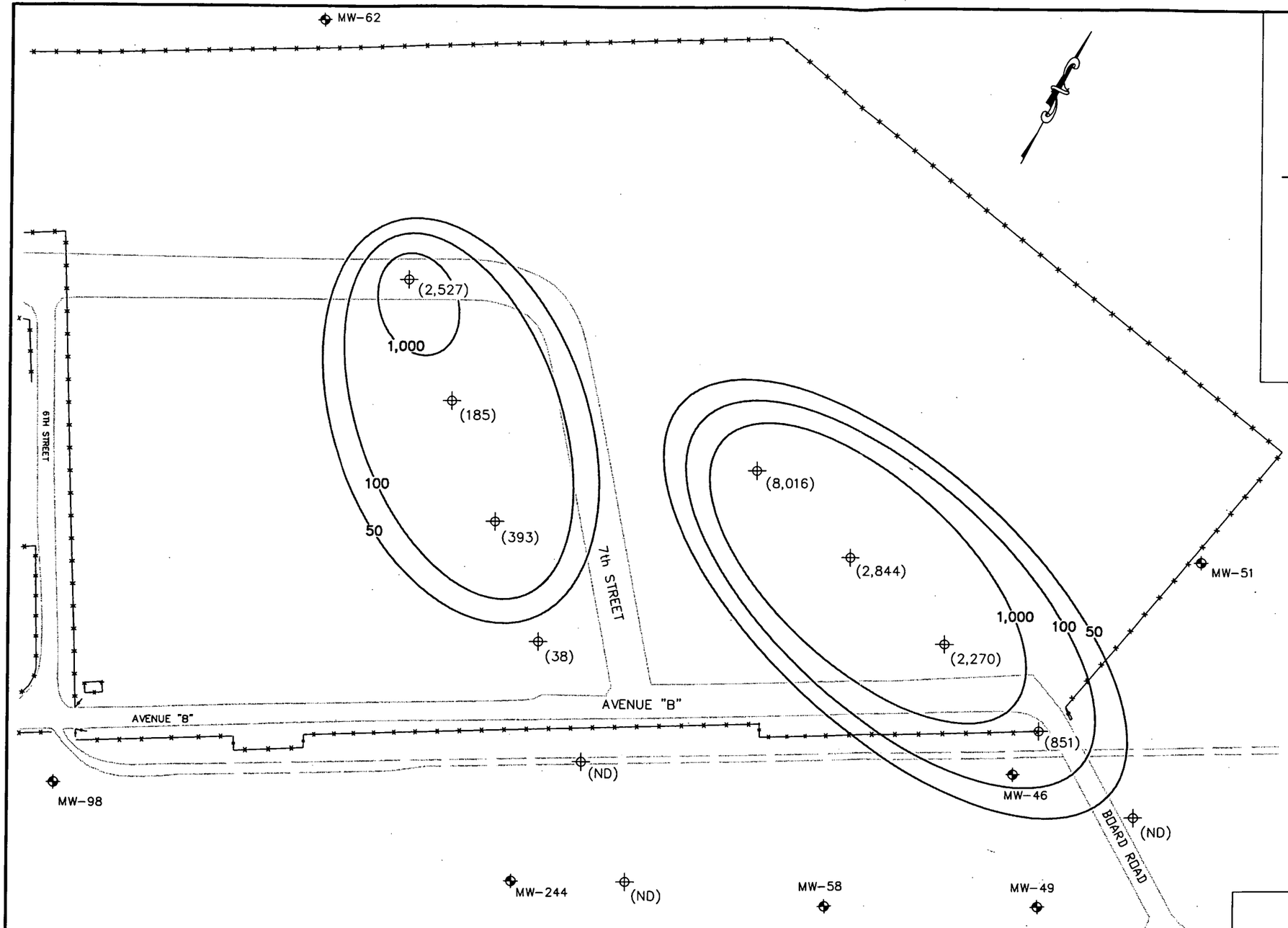
3 WASHINGTON CENTER
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-5.DWG



LEGEND

(2,270) PREDICTED DISSOLVED-PHASE TPH-GRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

—1,000— INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-GRO CONCENTRATION ISOPLETH

MW-049 MONITORING WELL LOCATION

CHAIN LINK FENCE

NOTE:

1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-GRO CONCENTRATIONS PROVIDED IN FIGURE 11.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-GRO PLUME PATTERNS.

TPH AS GASOLINE RANGE ORGANICS (TPH-GRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

0 85
APPROXIMATE SCALE (ft)

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600035\CAD\FFBIOSCREEN\FIG5-6.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 6 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 18

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

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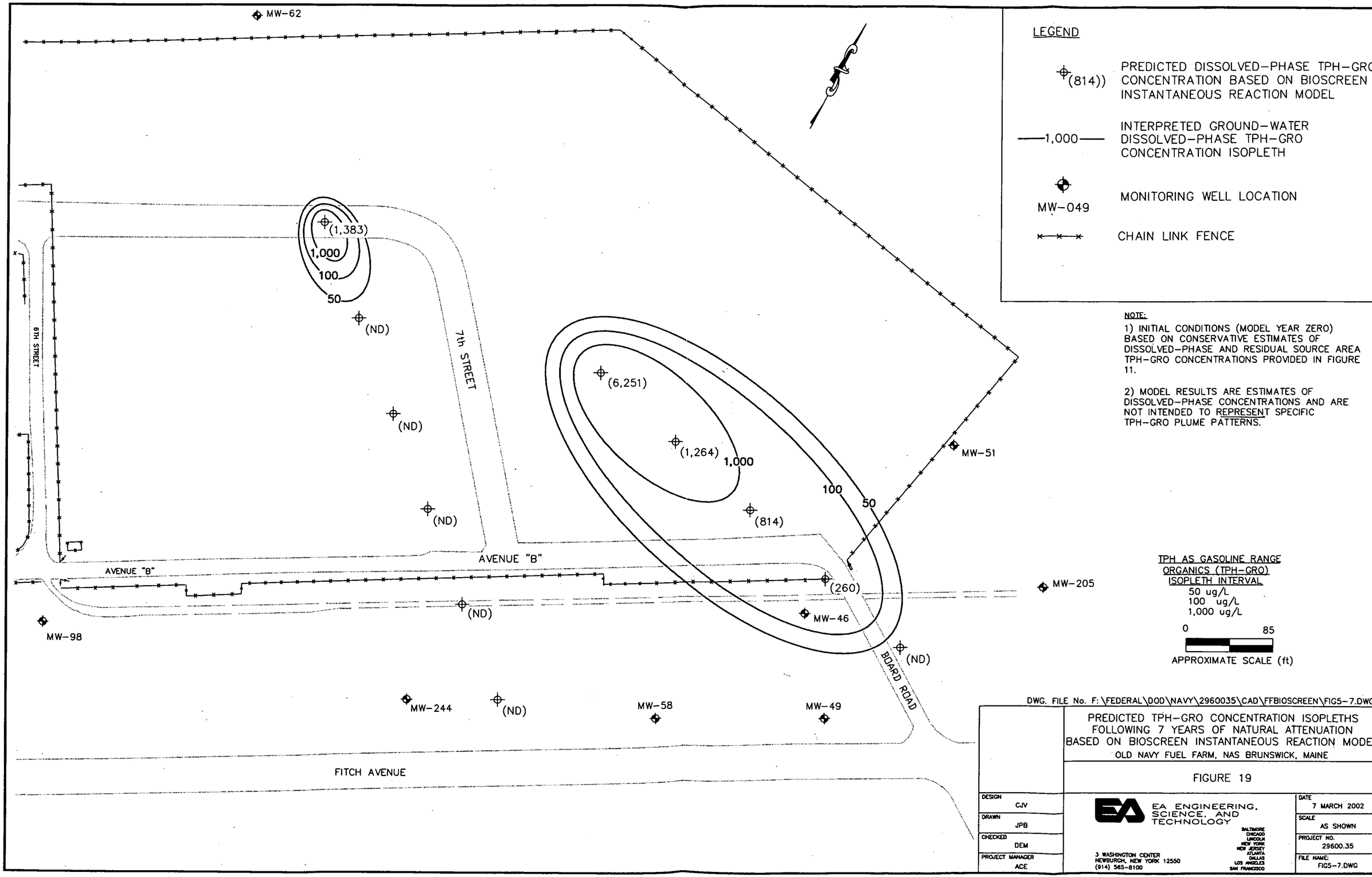
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-6.DWG



LEGEND

- (814)) PREDICTED DISSOLVED-PHASE TPH-GRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL
- —1,000— INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-GRO CONCENTRATION ISOPLETH
- MW-049 MONITORING WELL LOCATION
- CHAIN LINK FENCE

NOTE:

1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-GRO CONCENTRATIONS PROVIDED IN FIGURE 11.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-GRO PLUME PATTERNS.

TPH AS GASOLINE RANGE ORGANICS (TPH-GRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

0 85

APPROXIMATE SCALE (ft)

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\FIG5-7.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 7 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 19

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

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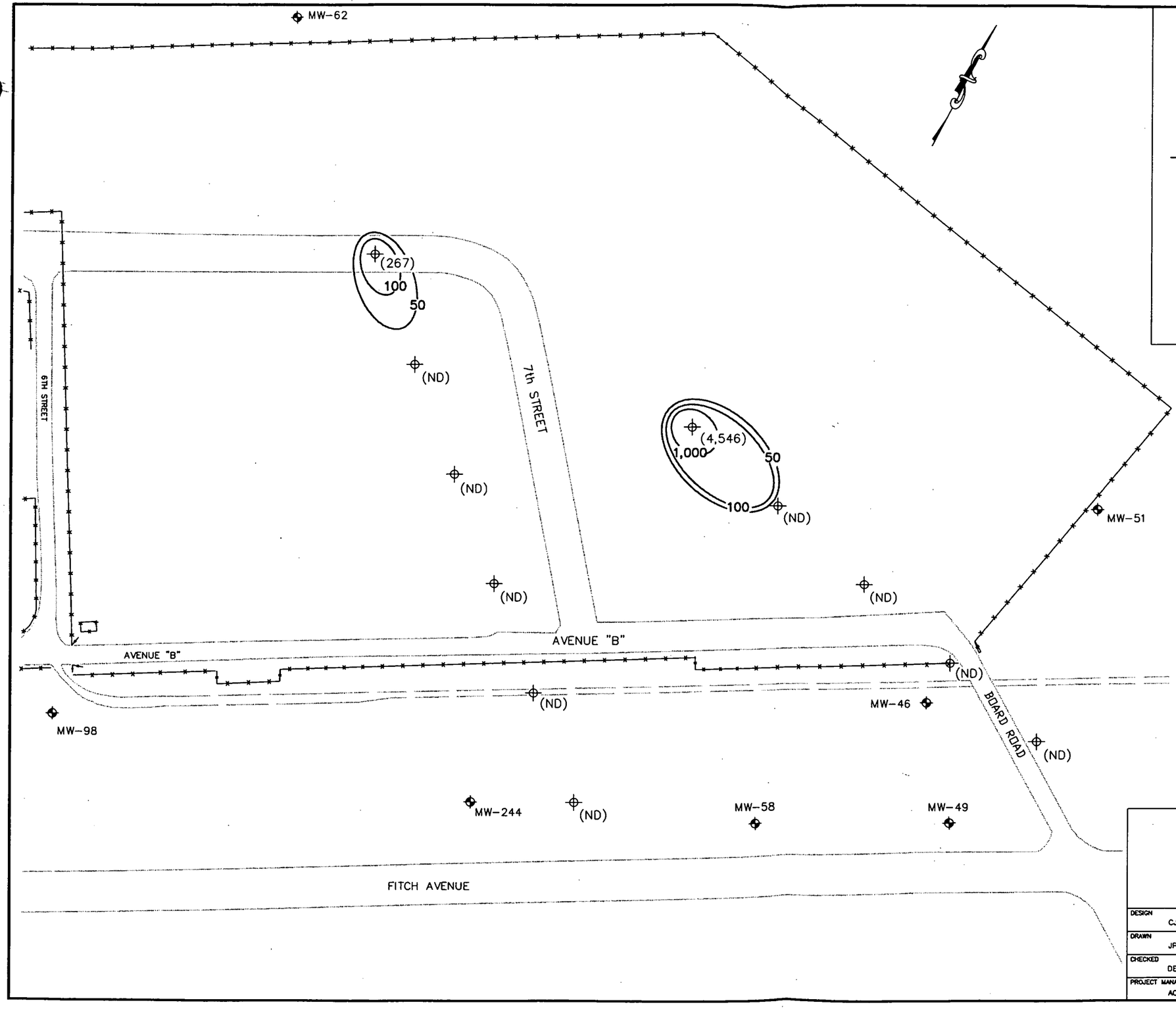
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-7.DWG



LEGEND

(ND) — PREDICTED DISSOLVED-PHASE TPH-GRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

1,000 — INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH

MW-049 — MONITORING WELL LOCATION

CHAIN LINK FENCE

NOTE:

1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-GRO CONCENTRATIONS PROVIDED IN FIGURE 11.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-GRO PLUME PATTERNS.

3) EASTERN TPH-GRO PLUME PREDICTED TO REACH NON-DETECT CONCENTRATIONS BY MODEL YEAR 11.

4) WESTERN TPH-GRO PLUME PREDICTED TO REACH NON-DETECT CONCENTRATIONS BY MODEL YEAR 9.

TPH AS GASOLINE RANGE ORGANICS (TPH-GRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

0 85

APPROXIMATE SCALE (ft)

DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\FIG5-8.DWG

PREDICTED TPH-GRO CONCENTRATION ISOPLETHS FOLLOWING 8 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 20

DESIGN	CJV
DRAWN	JPB
CHECKED	DEM
PROJECT MANAGER	ACE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY
BALTIMORE CHICAGO LINCOLN NEW YORK NEW JERSEY ATLANTA DALLAS LOS ANGELES SAN FRANCISCO
3 WASHINGTON CENTER
NEWBURGH, NEW YORK 12550
(914) 565-8100

DATE	7 MARCH 2002
SCALE	AS SHOWN
PROJECT NO.	29600.35
FILE NAME:	FIG5-8.DWG

LEGEND

(578) PREDICTED DISSOLVED-PHASE TPH-DRO CONCENTRATION BASED ON BIOSCREEN FISRT-ORDER DECAY MODEL

1,000 INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH

MW-049 MONITORING WELL LOCATION

CHAIN LINK FENCE

NOTE:
1) INITIAL CONDITIONS (IE. MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-DRO CONCENTRATIONS PROVIDED IN FIGURE 12.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-DRO PLUME PATTERNS.

OLD NAVY FUEL FARM

MW-096
MW-063
MW-062
MW-051
MW-205
(9,728)
(2,431)
(757)
(250)
(85)
(9,808)
(1,931)
(578)
(188)
MW-046
(64)
(22)
1,000
100
50
MW-049
(8)
(3)
(1)
(ND)
MW-206
(29)
MW-058
(10)
(3)
MW-244
(1)
(ND)
MW-207
MW-098
MW-210
MW-208
MW-245
MW-209R
(294)
150
3
28
223
13
FIFTH STREET
SIXTH STREET
AVENUE B
FITCH AVENUE
BOARD ROAD
MWR STORAGE SHED
PARKING
PARKING
PARKING

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL

50 ug/L
100 ug/L
1,000 ug/L

165' 0 165'

APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\FIG5-9.DWG

PREDICTED TPH-DRO CONCENTRATION ISOPLETHS FOLLOWING 10 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 21

DESIGN	SY
DRAWN	SAP
CHECKED	CJV
PROJECT MANAGER	AE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100
ALASKA CALIFORNIA DELAWARE FLORIDA HAWAII MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

DATE	06 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-

LEGEND

(567) PREDICTED DISSOLVED-PHASE TPH-DRO CONCENTRATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL

1,000 INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH

MW-049 MONITORING WELL LOCATION

CHAIN LINK FENCE

NOTE:
1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-DRO CONCENTRATIONS PROVIDED IN FIGURE 12.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-DRO PLUME PATTERNS.

OLD NAVY FUEL FARM

MW-096
MW-063
MW-062
MW-051
MW-205
(9,675)
(2,418)
(753)
(248)
(85)
(9,619)
(1,894)
(567)
(185)
MW-046
(63)
(22)
1,000
100
50
MW-049
(8)
(3)
(1)
(ND)
MW-206
(29)
MW-058
(10)
(4)
(1)
(ND)
MW-207
MW-244
MW-098
MW-210
MW-208
MW-245
MW-209R
FIFTH STREET
SIXTH STREET
AVENUE B
FITCH AVENUE
BOARD ROAD
MWR STORAGE SHED
PARKING
3
28
223
13
294
150

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

165' 0 165'
APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\FIG5-10.DWG

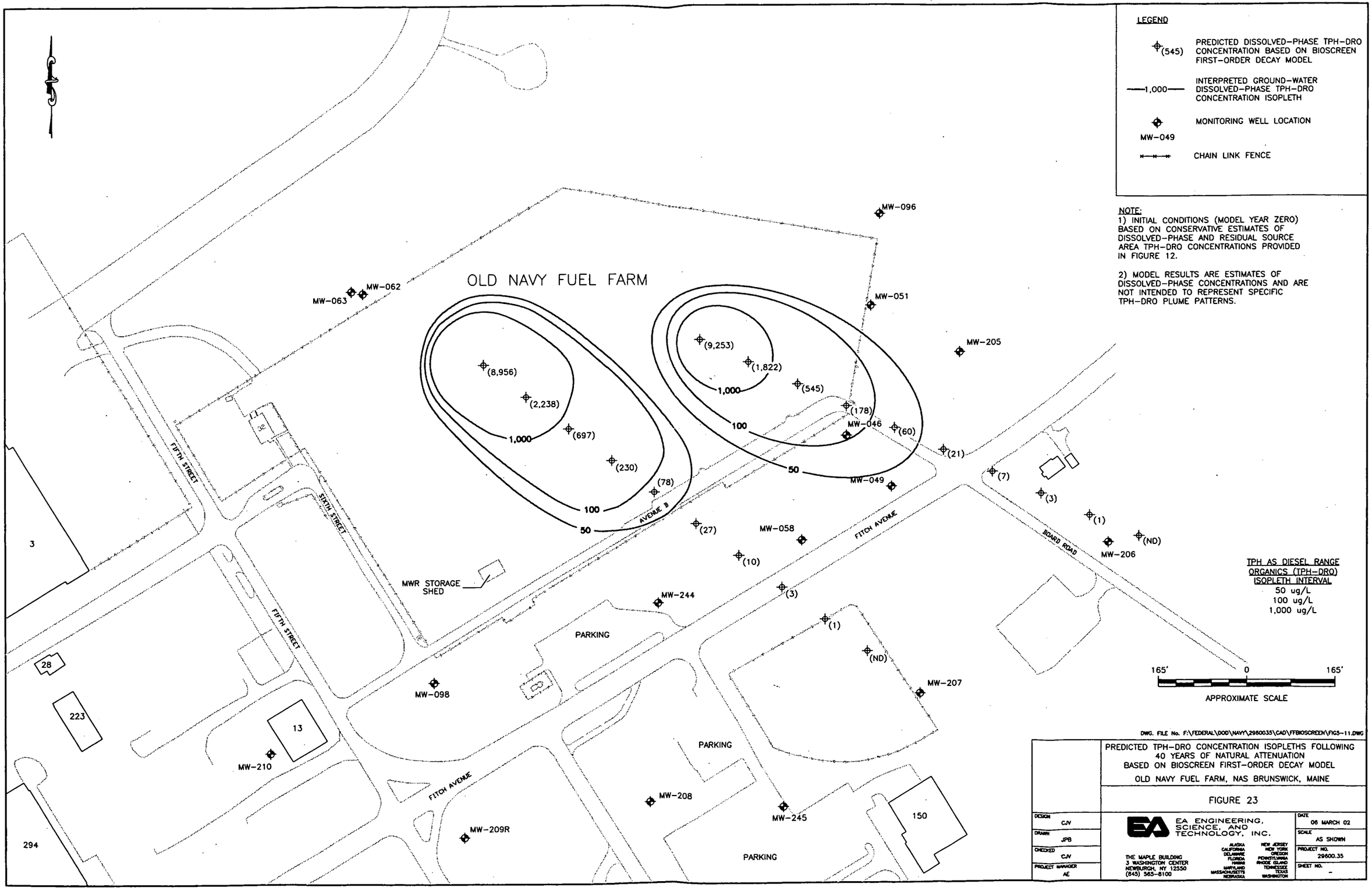
PREDICTED TPH-DRO CONCENTRATION ISOPLETHS FOLLOWING 20 YEARS OF NATURAL ATTENUATION
BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 22

DESIGN	CJV
DRAWN	JPB
CHECKED	CJV
PROJECT MANAGER	AE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100
ALASKA CALIFORNIA DELAWARE FLORIDA HAWAII MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

DATE	08 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-


LEGEND
(545) PREDICTED DISSOLVED-PHASE TPH-DRO CONCENTRATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL
1,000 INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH
MW-049 MONITORING WELL LOCATION
CHAIN LINK FENCE
NOTE:
1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-DRO CONCENTRATIONS PROVIDED IN FIGURE 12.
2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-DRO PLUME PATTERNS.
OLD NAVY FUEL FARM
MW-096
MW-062
MW-063
MW-051
MW-205
(9,253)
(1,822)
(8,956)
(2,238)
(545)
1,000
(178)
MW-046
(60)
100
(697)
(21)
(230)
50
MW-049
(78)
(7)
(3)
(1)
(ND)
MW-206
(27)
MW-058
(10)
(3)
MW-244
(1)
(ND)
MW-207
MW-098
MW-210
MW-208
MW-245
MW-209R
FIFTH STREET
SIXTH STREET
AVENUE B
FITCH AVENUE
BOARD ROAD
MWR STORAGE SHED
PARKING
3
28
223
13
294
150
TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L
165' 0 165'
APPROXIMATE SCALE
DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\FIGS-11.DWG
PREDICTED TPH-DRO CONCENTRATION ISOPLETHS FOLLOWING 40 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN FIRST-ORDER DECAY MODEL
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE
FIGURE 23
DESIGN CJV
DRAWN JPB
CHECKED CJV
PROJECT MANAGER AE
EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100
ALASKA CALIFORNIA DELAWARE FLORIDA HAWAII MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON
DATE 06 MARCH 02
SCALE AS SHOWN
PROJECT NO. 29600.35
SHEET NO. -

LEGEND

(2,298) PREDICTED DISSOLVED-PHASE TPH-DRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

1,000 INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH

MW-049 MONITORING WELL LOCATION

CHAIN LINK FENCE

(ND)* SIMULATED DATA NOT AVAILABLE BIOSCREEN MODEL ASSUMES INITIAL DOWNGRADIENT CONCENTRATION = 0.0.

NOTE:
1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-DRO CONCENTRATIONS PROVIDED IN FIGURE 12.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-DRO PLUME PATTERNS.

OLD NAVY FUEL FARM

MW-096
MW-051
MW-205
MW-062
MW-063
(6,954)
(5,656)
(3,088)
(3,404)
(2,298)
(1,674)
MW-046
(2,798)
(558)
(2,448)
(1,764)
1,000
100
50
MW-049
(ND)*
MW-058
(ND)*
MW-206
BOARD ROAD
FITCH AVENUE
AVENUE B
SIXTH STREET
FIFTH STREET
MWR STORAGE SHED
MW-244
PARKING
MW-098
MW-207
PARKING
MW-208
MW-245
MW-209R
MW-210
PARKING
3
28
223
13
294
150

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

165' 0 165'
APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\000\NAVY\2960035\CAD\FFBIOSCREEN\FIGS-12.DWG

PREDICTED TPH-DRO CONCENTRATION ISOPLETHS FOLLOWING 10 YEARS OF NATURAL ATTENUATION
BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL
OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 24

DESIGN	CJV
DRAWN	JPB
CHECKED	CJV
PROJECT MANAGER	AE

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DATE	06 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-

LEGEND

(1,486) PREDICTED DISSOLVED-PHASE TPH-DRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

—1,000— INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH

MW-049 MONITORING WELL LOCATION

CHAIN LINK FENCE

(ND)* SIMULATED DATA NOT AVAILABLE BIOSCREEN MODEL ASSUMES INITIAL DOWNGRADIENT CONCENTRATION = 0.0.

NOTE:
1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-DRO CONCENTRATIONS PROVIDED IN FIGURE 12.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-DRO PLUME PATTERNS.

OLD NAVY FUEL FARM

MW-096 MW-063 MW-062 MW-051 MW-205 MW-046 MW-049 MW-058 MW-206 MW-244 MW-098 MW-207 MW-210 MW-208 MW-245 MW-209R

(5,856) (4,192) (2,211) (2,129) (1,486) (1,044) (1,558) (635) (136) (1,371) (ND) (1,350) (1,310) (960) (ND)* (ND)*

1,000 100 50 1,000 100 50

FIFTH STREET SIXTH STREET FIFTH STREET FITCH AVENUE AVENUE B FITCH AVENUE EDARD ROAD

MWR STORAGE SHED PARKING PARKING PARKING

3 28 223 13 294 150

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

165' 0 165'
APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\2960035\CAD\FFBIOSCREEN\FIG5-13.DWG

PREDICTED TPH-DRO CONCENTRATION ISOPLETHS FOLLOWING 14 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 25

DESIGN	CJV
DRAWN	JPB
CHECKED	CJV
PROJECT MANAGER	AE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 565-8100
ALASKA CALIFORNIA DELAWARE FLORIDA HAWAII MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

DATE	06 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-

LEGEND

(681) PREDICTED DISSOLVED-PHASE TPH-DRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

1,000 INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH

MW-049 MONITORING WELL LOCATION

CHAIN LINK FENCE

NOTE:
1) INITIAL CONDITIONS (IE. MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-DRO CONCENTRATIONS PROVIDED IN FIGURE 12.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-DRO PLUME PATTERNS.

OLD NAVY FUEL FARM

MW-096
MW-063
MW-062
MW-051
MW-205
MW-046
MW-049
MW-058
MW-206
MW-244
MW-098
MW-207
MW-210
MW-208
MW-209R
MW-245

(4,820) (1,378) (2,863) (966) (399) (199) (191) (284) (411) (474) (300) (681) (262) (ND) (ND) (ND)

1,000 100 50 1,000 100 50

FIFTH STREET
SIXTH STREET
AVENUE B
FITCH AVENUE
BOARD ROAD
MWR STORAGE SHED
PARKING
PARKING
PARKING

3 28 223 13 294 150 32 52

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

165' 0 165'
APPROXIMATE SCALE

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\FIGS-15.DWG

PREDICTED TPH-DRO CONCENTRATION ISOPLETHS FOLLOWING 18 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 26

DESIGN	CJV
DRAWN	JPB
CHECKED	CJV
PROJECT MANAGER	AE

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
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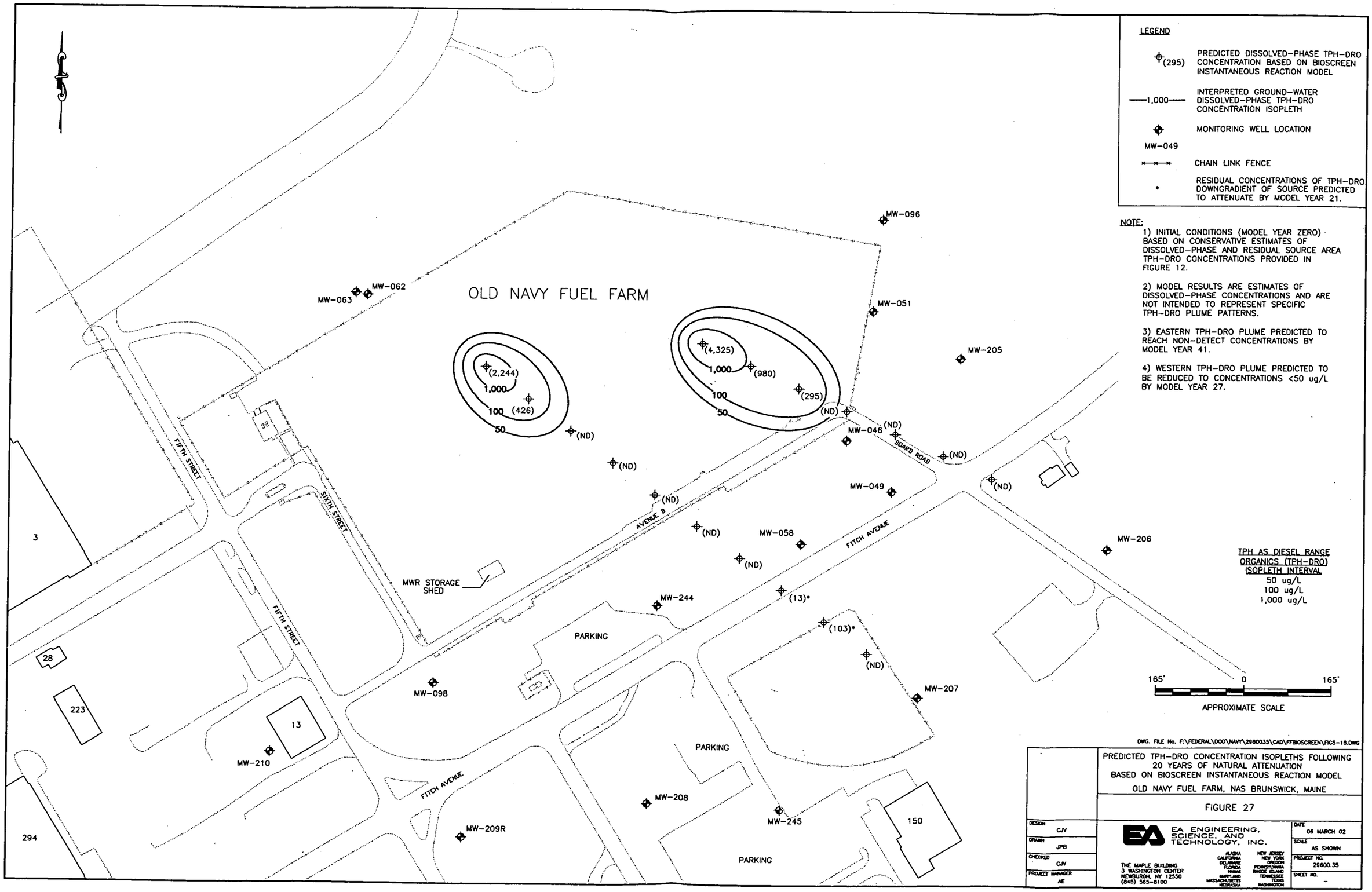
NEWBURGH, NY 12550
(845) 565-8100
ALASKA CALIFORNIA DELAWARE FLORIDA HAWAII MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

DATE	06 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-



LEGEND

(295)	PREDICTED DISSOLVED-PHASE TPH-DRO CONCENTRATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL
1,000	INTERPRETED GROUND-WATER DISSOLVED-PHASE TPH-DRO CONCENTRATION ISOPLETH
MW-049	MONITORING WELL LOCATION
	CHAIN LINK FENCE
•	RESIDUAL CONCENTRATIONS OF TPH-DRO DOWNGRADIENT OF SOURCE PREDICTED TO ATTENUATE BY MODEL YEAR 21.

NOTE:

1) INITIAL CONDITIONS (MODEL YEAR ZERO) BASED ON CONSERVATIVE ESTIMATES OF DISSOLVED-PHASE AND RESIDUAL SOURCE AREA TPH-DRO CONCENTRATIONS PROVIDED IN FIGURE 12.

2) MODEL RESULTS ARE ESTIMATES OF DISSOLVED-PHASE CONCENTRATIONS AND ARE NOT INTENDED TO REPRESENT SPECIFIC TPH-DRO PLUME PATTERNS.

3) EASTERN TPH-DRO PLUME PREDICTED TO REACH NON-DETECT CONCENTRATIONS BY MODEL YEAR 41.

4) WESTERN TPH-DRO PLUME PREDICTED TO BE REDUCED TO CONCENTRATIONS <50 ug/L BY MODEL YEAR 27.

TPH AS DIESEL RANGE ORGANICS (TPH-DRO) ISOPLETH INTERVAL
50 ug/L
100 ug/L
1,000 ug/L

DWG. FILE No. F:\FEDERAL\DOD\NAVY\29600.35\CAD\FFBIOSCREEN\FIGS-16.DWG

PREDICTED TPH-DRO CONCENTRATION ISOPLETHS FOLLOWING 20 YEARS OF NATURAL ATTENUATION BASED ON BIOSCREEN INSTANTANEOUS REACTION MODEL

OLD NAVY FUEL FARM, NAS BRUNSWICK, MAINE

FIGURE 27

DESIGN	CJV
DRAWN	JPB
CHECKED	CJV
PROJECT MANAGER	AE
DATE	06 MARCH 02
SCALE	AS SHOWN
PROJECT NO.	29600.35
SHEET NO.	-

EA ENGINEERING, SCIENCE, AND TECHNOLOGY, INC.
THE MAPLE BUILDING
3 WASHINGTON CENTER
NEWBURGH, NY 12550
(845) 563-8100
ALASKA CALIFORNIA DELAWARE FLORIDA MAINE MARYLAND MASSACHUSETTS NEBRASKA NEW JERSEY NEW YORK OREGON PENNSYLVANIA RHODE ISLAND TENNESSEE TEXAS WASHINGTON

TABLE 1 CALCULATION FOR RESIDUAL TOTAL PETROLEUM HYDROCARBON SOLUBLE MASS AT APPROXIMATED POINT SOURCE RELEASE AREAS

Estimated Area[(a)]	Source Thickness	Source Volume	Residual Soil Concentration[(b)]	Soluble Mass
TPH-GRO EAST – APPROXIMATED POINT SOURCE RELEASE AREA CALCULATION				
50,000 ft^2	3 ft	150,000 ft^3	124 mg/kg	**790 kg**
TPH-GRO WEST – APPROXIMATED POINT SOURCE RELEASE AREA CALCULATION				
45,000 ft^2	3 ft	135,000 ft^3	246 mg/kg	**1,410 kg**
TPH-DRO EAST – APPROXIMATED POINT SOURCE RELEASE AREA CALCULATION				
44,000 ft^2	3 ft	132,000 ft^3	124 mg/kg	**695 kg**
TPH-DRO WEST – APPROXIMATED POINT SOURCE RELEASE AREA CALCULATION				
22,000 ft^2	3 ft	66,000 ft^3	246 mg/kg	**689 kg**

(a) Estimated residual source areas for TPH-GRO based on total dissolved-phase TPH-GRO concentration isopleths >100 µg/L as shown on Figure 11. Estimated residual source areas for TPH-DRO based on total dissolved-phase TPH-DRO concentration isopleths >1,000 µg/L as shown on Figure 12.

(b) Residual source area soil concentrations are conservatively estimated based on area-weighted averages of maximum confirmatory sidewall sample concentrations. Confirmatory soil samples collected from remedial excavation areas B15, B17, C16, D11, E14, E17, and G14 (eastern); and B7, G7, H8, I6, TP6, TP7/D7, and TP24 (western) were excavated during September-November 2000 (Foster Wheeler 2002).

NOTE: TPH = Total petroleum hydrocarbon.
GRO = Gasoline range organic.
DRO = Diesel range organic.
Residual Soluble Mass (kg) = Volume (ft^3) × 28.3 L/ft^3 × Estimated Soil Bulk Density (1.5 kg/L) × Residual Concentration (mg/kg) × 10^{-6} kg/mg.

TABLE 2 BIOSCREEN MODEL INPUT PARAMETER SUMMARY

Parameter Typical Range[a]	TPH-GRO	Source	TPH-DRO	Source
1. HYDROGEOLOGY				
Hydraulic Conductivity *0.001-1*	0.0063 cm/s	1992 Remedial Investigation Report (O'Brien & Gere 1992)	0.0063 cm/s	1992 Remedial Investigation Report (O'Brien & Gere 1992)
Hydraulic Gradient (i)	0.0073 ft/ft	December 2000 ground-water contour map (EA 2001a)	0.0073 ft/ft	December 2000 ground-water contour map (EA 2001a)
Porosity (n) *0.2-0.35*	0.35	1992 Remedial Investigation Report, specific to the Old Navy Fuel Farm fill material and native sand (O'Brien & Gere 1992)	0.35	1992 Remedial Investigation Report, specific to the Old Navy Fuel Farm fill material and native sand (O'Brien & Gere 1992)
2. DISPERSION				
Eastern Old Navy Fuel Farm Estimated Plume Length *50-500 ft (BTEX)*	340 ft (calibrated)	Dissolved-phase TPH-GRO concentration isopleth map based on June 1999 sampling event (EA 1997a)	660 ft (calibrated)	Dissolved-phase TPH-GRO concentration isopleth map based on June 1999 sampling event (EA 2000)
Western Old Navy Fuel Farm Estimated Plume Length *50-500 ft (BTEX)*	290 ft (calibrated)	Dissolved-phase TPH-GRO concentration isopleth map based on June 1999 sampling event (EA 1997a)	600 ft (calibrated)	Dissolved-phase TPH-GRO concentration isopleth map based on June 1999 sampling event (EA 2000)
3. ADSORPTION				
Retardation Factor (R) *1-2*	1.5	Mid-range of suggested value from BIOSCREEN users manual for BTEX in shallow aquifers	2.09	TPH-DRO retardation factor developed at Vandenberg Air Force Base (Concurrent Technologies, Inc. 1999)
4a. FIRST-ORDER BIODEGRATION DECAY COEFFICIENT				
First-Order Decay Coefficient (λ) *0.038-1*	TBD	This parameter is to be used for calibration of the BIOSCREEN model	TBD	This parameter is to be used for calibration of the BIOSCREEN model

(a) Typical range based on Air Force Center for Environmental Excellence studies conducted at 28 petroleum hydrocarbon release sites, as provided with the BIOSCREEN User's Manual.

NOTE: TPH = Total petroleum hydrocarbon.
GRO = Gasoline range organic.
DRO = Diesel range organic.
BTEX = Benzene, toluene, ethylbenzene, and total xylene.
TBD = To be determined during model calibration.

Parameter Typical Range[a]	TPH-GRO	Source	TPH-DRO	Source
4b. INSTANTANEOUS REACTION MODEL				
Delta Oxygen *0.4-12.7 mg/L*	4.7 mg/L	1996 baseline natural attenuation data (EA 1997a)	1.41 mg/L	30% of BTEX value to account for preferential electron acceptor demand
Delta Nitrate *0-69.7 mg/L*	28.9 mg/L	1996 baseline natural attenuation data (EA 1997a)	8.67 mg/L	30% of BTEX value to account for preferential electron acceptor demand
Observed Ferrous Iron *0-599 mg/L*	1.5 mg/L	1996 baseline natural attenuation data (EA 1997a)	0.45 mg/L	30% of BTEX value to account for preferential electron acceptor demand
Delta Sulfate *0-109.2 mg/L*	79.9 mg/L	1996 baseline natural attenuation data (EA 1997a)	23.98 mg/L	30% of BTEX value to account for preferential electron acceptor demand
Observed Methane (Dissolved) *0-48.4 mg/L*	17.7 mg/L	Recent data and interpretation of vapor-phase methane data collected during August 1996.	5.19 mg/L	30% of BTEX value to account for preferential electron acceptor demand.
5. GENERAL				
Model Length *10-1,000 ft*	1,000 ft	Appropriate for potential plume	1,000 ft	Appropriate for potential plume
Model Width *10-1,000 ft*	200 ft	Appropriate for plume width	200 ft	Appropriate for plume width
Simulation Time *1-1,000 years*	TBD	As required to satisfy TPH-GRO closure condition	TBD	As required to satisfy TPH-DRO closure condition
6. SOURCE DATA				
Source Zone Thickness *5-50 ft*	3 ft	Test pit sampling and field observations (Foster Wheeler 2001); seasonal ground-water elevation fluctuations of 2-3 ft below ground surface	3 ft	Test pit sampling and field observations (Foster Wheeler 2001); seasonal ground-water elevation fluctuations of 2-3 ft below ground surface
Concentration in Source Zones *0.01-120 mg/L*	20 mg/L (eastern) 10 mg/L (western)	Maximum total BTEX concentration reported at the Old Navy Fuel Farm (1990-1999), conservative but reasonable	10 mg/L (eastern) 10 mg/L (western)	Maximum total BTEX concentration reported at the Old Navy Fuel Farm (1990-1999), conservative but reasonable
Soluble Mass in Soil *0.1-100,000 kg*	790 kg (eastern) 1,410 kg (western)	See soluble mass calculation Table 1	695 kg (eastern) 689 kg (western)	See soluble mass calculation Table 3
7. FIELD DATA FOR COMPARISON				
Contaminant concentration data at known time intervals	Historical BTEX and TPH-GRO data	IT Corp., HRP Inc., and EA site investigations at the Old Navy Fuel Farm – see Table 3	Historical TPH-DRO data	EA site investigations at the Old Navy Fuel Farm (1996-2001)

TABLE 3 BIOSCREEN TOTAL PETROLEUM HYDROCARBON-GASOLINE RANGE ORGANIC CALIBRATION DATA REPORTED AS PREDICTED DISSOLVED-PHASE BENZENE, TOLUENE, ETHYLBENZENE, AND TOTAL XYLENE CONCENTRATIONS VERSUS HISTORICAL GROUND-WATER SAMPLING DATA COLLECTED DURING 1990-1996

Distance from Source (ft)	Predicted Dissolved-Phase BTEX Concentration[a]	
	Predicted Value (µg/L) at 6 Years	Historical Data[b] (µg/L)
First-Order Decay Biodegradation Model		
0	23,913	LNAPL[c]
100	3,943	4,000
200	692	900
300	123	100
400	22	50
500	4	5
600	1	1
700	0	ND
Instantaneous Reaction Biodegradation Model		
0	14,939	LNAPL[c]
100	13,406	4,000
200	11,978	900
300	8,210	100
400	190	50
500	0	5
600	0	1
700	0	ND

(a) Total BTEX used as a surrogate compound group to represent total petroleum hydrocarbon-gasoline range organics.
(b) Concentrations represent data based on 7-8 August 1996 interpreted dissolved-phase BTEX concentration isopleths (EA 1997a).
(c) Based on site-specific analytical data, the dissolved-phase total BTEX concentration in areas exhibiting LNAPL is assumed to be >20,000 µg/L. Initial (i.e., year zero) model source area concentration assumed to be 25,000 µg/L.

NOTE: BTEX = Benzene, toluene, ethylbenzene, and total xylene.
LNAPL = Light, non-aqueous phase liquid.
ND = Not detected.

TABLE 4 BIOSCREEN MODELING RESULTS FROM FIRST-ORDER DECAY SIMULATION OF TOTAL PETROLEUM HYDROCARBON-GASOLINE RANGE ORGANIC DISSOLVED-PHASE PLUMES

Distance from Approximated Residual Source Area (ft)	Modeled Time (years)										
	5	10	20	40	80	160	320	640	1,280	1,620	2,405
TPH-GRO EASTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)											
0	19,633	19,272	18,571	17,243	14,867	11,051	6,106	1,864	174	49	3
100	1,964	1,928	1,858	1,725	1,487	1,106	611	187	17	5	<1
200	277	272	262	244	210	156	86	26	2	1	<1
300	42	41	40	37	32	24	13	4	<1	<1	<1
400	7	6	6	6	5	4	2	1	<1	<1	<1
500	1	1	1	1	1	1	<1	<1	<1	<1	<1
600	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
TPH-GRO WESTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)											
0	9,938	9,876	9,754	9,514	9,051	8,192	6,711	4,504	2,028	1,328	49
100	995	989	977	953	906	820	672	451	203	133	5
200	140	139	138	134	128	116	95	64	29	19	7
300	21	21	21	20	19	17	14	10	4	3	1
400	3	3	3	3	3	3	2	1	1	<1	<1
500	<1	1	1	<1	<1	<1	<1	<1	<1	<1	<1
600	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

NOTE: TPH = Total petroleum hydrocarbon.
GRO = Gasoline range organic.
Eastern dissolved-phase TPH-GRO plume initial (i.e., current) maximum concentration conservatively estimated to be 20,000 µg/L.
Western dissolved-phase TPH-GRO plume initial (i.e., current) maximum concentration conservatively estimated to be 10,000 µg/L.
First-order decay model assumes no biodegradation in the source area, therefore, future dissolved-phase concentrations are significantly over-estimated in the vicinity of the source area.

TABLE 5 BIOSCREEN MODELING RESULTS FROM INSTANTANEOUS REACTION SIMULATION OF TOTAL PETROLEUM HYDROCARBON-GASOLINE RANGE ORGANIC DISSOLVED-PHASE PLUME

Distance from Approximated Residual Source Area (ft)	Modeled Time (years)									
	1	2	3	4	5	6	7	8	9	10
TPH-GRO EASTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)										
0	17,825	15,724	13,696	11,736	9,844	8,016	6,251	4,546	2,899	1,309[a]
100	<1[b]	2,195	6,448	5,906	4,442	2,844	1,264	<1	<1	<1
200	<1[b]	<1[b]	<1[b]	2,696	3,342	2,270	814	<1	<1	<1
300	<1[b]	<1[b]	<1[b]	<1[b]	<1[a]	851	260	<1	<1	<1
400	<1[b]	<1[b]	<1[b]	<1[b]	<1[a]	<1	<1	<1	<1	<1
500	<1[b]	<1[b]	<1[b]	<1[b]	<1[a]	<1	<1	<1	<1	<1
TPH-GRO WESTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)										
0	8,678	7,388	6,128	4,898	3,698	2,527	1,383	267	<1	<1
100	<1[b]	<1[b]	2,461	2,244	1,270	185	<1	<1	<1	<1
200	<1[b]	<1[b]	<1[b]	243	1,078	393	<1	<1	<1	<1
300	<1[b]	<1[b]	<1	<1	<1[b]	38	<1	<1	<1	<1
400	<1[b]	<1[b]	<1	<1	<1	<1	<1	<1	<1	<1
500	<1[b]	<1[b]	<1	<1	<1	<1	<1	<1	<1	<1

(a) Residual source area and downgradient dissolved-phase TPH-GRO concentrations predicted to be zero at BIOSCREEN model year 11.
(b) Simulated data not available; BIOSCREEN model assumes initial downgradient concentration to be zero.

NOTE: TPH = Total petroleum hydrocarbon.
GRO = Gasoline range organic.
Eastern dissolved-phase TPH-GRO plume initial (i.e., current) maximum concentration conservatively estimated to be 20,000 µg/L.
Western dissolved-phase TPH-GRO plume initial (i.e., current) maximum concentration conservatively estimated to be 10,000 µg/L.

TABLE 6 BIOSCREEN MODELING RESULTS FROM INSTANTANEOUS REACTION SIMULATION OF TOTAL PETROLEUM HYDROCARBON-DIESEL RANGE ORGANIC DISSOLVED-PHASE PLUME

Distance from Approximated Residual Source Area (ft)	Modeled Time (years)									
	10	12	14	16	18	20	25	30	35	40
TPH-DRO EASTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)										
0	6,954	6,397	5,856	5,330	4,820	4,325	3,149	2,056	1,041	98[a]
100	3,088	2,645	2,211	1,788	1,378	980	33	<1	<1	<1
200	2,298	1,901	1,486	1,078	681	295	<1	<1	<1	<1
300	1,647	1,416	1,044	651	262	<1	<1	<1	<1	<1
400	558	853	635	285	<1	<1	<1	<1	<1	<1
500	<1[b]	<1[b]	136	<1	<1	<1	<1	<1	<1	<1
600	<1[b]	<1[b]	<1	<1	<1	<1	<1	<1	<1	<1
TPH-DRO WESTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)										
0	5,656	4,907	4,192	3,512	2,863	2,244	822[c]	<1	NA	NA
100	3,404	2,753	2,129	1,534	966	426	<1	<1	NA	NA
200	2,798	2,176	1,558	965	399	<1	<1	<1	NA	NA
300	2,448	1,967	1,371	774	199	<1	<1	<1	NA	NA
400	1,764	1,817	1,350	772	191	<1	<1	<1	NA	NA
500	<1[b]	1,331	1,310	848	284	<1	<1	<1	NA	NA
600	<1[b]	<1[b]	960	871	411	<1	<1	<1	NA	NA
700	<1[b]	<1[b]	<1[b]	621	474	13	<1	<1	NA	NA
800	<1[b]	<1[b]	<1[b]	<1[b]	300	103	<1	<1	NA	NA
900	<1[b]	<1[b]	<1[b]	<1	<1	<1	<1	<1	NA	NA

(a) Eastern residual source area and downgradient dissolved-phase TPH-DRO concentrations predicted to be zero at BIOSCREEN model year 41.
(b) Simulated data not available, BIOSCREEN considers initial downgradient concentrations to be zero.
(c) Western residual source area and downgradient dissolved-phase TPH-DRO concentrations predicted to be <50 µg/L at BIOSCREEN model year 27.

NOTE: TPH = Total petroleum hydrocarbon.
DRO = Diesel range organic.
NA = Not analyzed (source depleted).
Eastern dissolved-phase TPH-DRO plume initial (i.e., current) maximum concentration conservatively estimated to be 10,000 µg/L.
Western dissolved-phase TPH-DRO plume initial (i.e., current) maximum concentration conservatively estimated to be 10,000 µg/L.

TABLE 7 BIOSCREEN MODELING RESULTS FROM FIRST-ORDER DECAY SIMULATION OF TOTAL PETROLEUM HYDROCARBON-DIESEL RANGE ORGANIC DISSOLVED-PHASE PLUMES

Distance from Approximated Residual Source Area (ft)	Modeled Time (years)										
	5	10	20	40	80	160	320	640	1,280	1,930	2,740
TPH-DRO EASTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)											
0	9,903	9,808	9,619	9,253	8,561	7,330	5,373	2,887	833	236	49
100	1,948	1,931	1,894	1,822	1,686	1,443	1,058	568	164	46	10
200	575	578	567	545	504	432	317	170	49	14	3
300	173	188	185	178	164	141	103	55	16	5	1
400	44	64	63	60	56	48	35	19	5	2	<1
500	8	22	22	21	19	17	12	7	2	1	<1
600	1	8	8	7	7	6	4	2	1	<1	<1
700	<1	3	3	3	2	2	2	1	<1	<1	<1
800	<1	1	1	1	1	1	1	<1	<1	<1	<1
900	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
TPH-DRO WESTERN FUEL FARM DISSOLVED-PHASE PLUME CONCENTRATION (µg/L)											
0	9,863	9,728	9,675	8,956	8,021	6,434	4,140	1,714	294	49	5
100	2,462	2,431	2,418	2,238	2,004	1,608	1,035	428	73	12	1
200	757	757	753	697	625	501	322	133	23	4	<1
300	230	250	248	230	206	165	106	44	8	1	<1
400	57	85	85	78	70	56	36	15	3	<1	<1
500	10	29	29	27	24	20	13	5	1	<1	<1
600	1	10	10	10	9	7	4	2	<1	<1	<1
700	<1	3	4	3	3	2	2	1	<1	<1	<1
800	<1	1	1	1	1	1	1	<1	<1	<1	<1
900	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

NOTE: TPH = Total petroleum hydrocarbon.
DRO = Diesel range organic.
Eastern dissolved-phase TPH-DRO plume initial (i.e., current) maximum concentration conservatively estimated to be 10,000 µg/L.
Western dissolved-phase TPH-DRO plume initial (i.e., current) maximum concentration conservatively estimated to be 10,000 µg/L.
First-Order Decay model assumes no biodegradation in the source area, therefore, future dissolved-phase concentrations are significantly over-estimated in the vicinity of the source areas.

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Appendix A

BIOSCREEN Calibration

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

NAS Brunswick
TPH-GRO Calibration
Run Name

Data Input Instructions:
1. Enter value directly ... or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below)

Variable* ▸ Data used directly in model
20 ◂ Value calculated by model (Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	Vs	136.0	(ft/yr)
or		↑ or	
Hydraulic Conductivity	K	6.3E-03	(cm/sec)
Hydraulic Gradient	i	0.0073	(ft/ft)
Porosity	n	0.35	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	20.0	(ft)
Transverse Dispersivity*	alpha y	2.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		↑ or	
Estimated Plume Length	Lp	630	(ft)

3. ADSORPTION

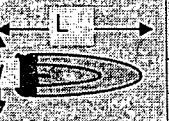
Retardation Factor*	R	1.5	(-)
or		↑ or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	38	(L/kg)
FractionOrganicCarbon	foc	5.7E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	2.0E+0	(per yr)
or		↑ or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.7	(mg/L)
Delta Nitrate*	NO3	28.9	(mg/L)
Observed Ferrous Iron*	Fe2+	1.5	(mg/L)
Delta Sulfate*	SO4	79.9	(mg/L)
Observed Methane*	CH4	17.7	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	6	(yr)



6. SOURCE DATA

Source Thickness in Sat Zone* 3 (ft)

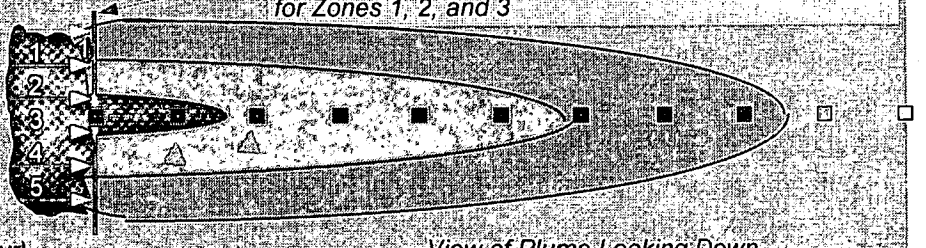
Source Zones:

Width* (ft)	Conc. (mg/L)*
25	10
30	20
20	25
30	20
25	10

Source Halflife (see Help):

20	90	(yr)
Inst. React.	1st Order	
Soluble Mass In Source NAPL Soil	1200	(Kg)

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
Concentration (mg/L)											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

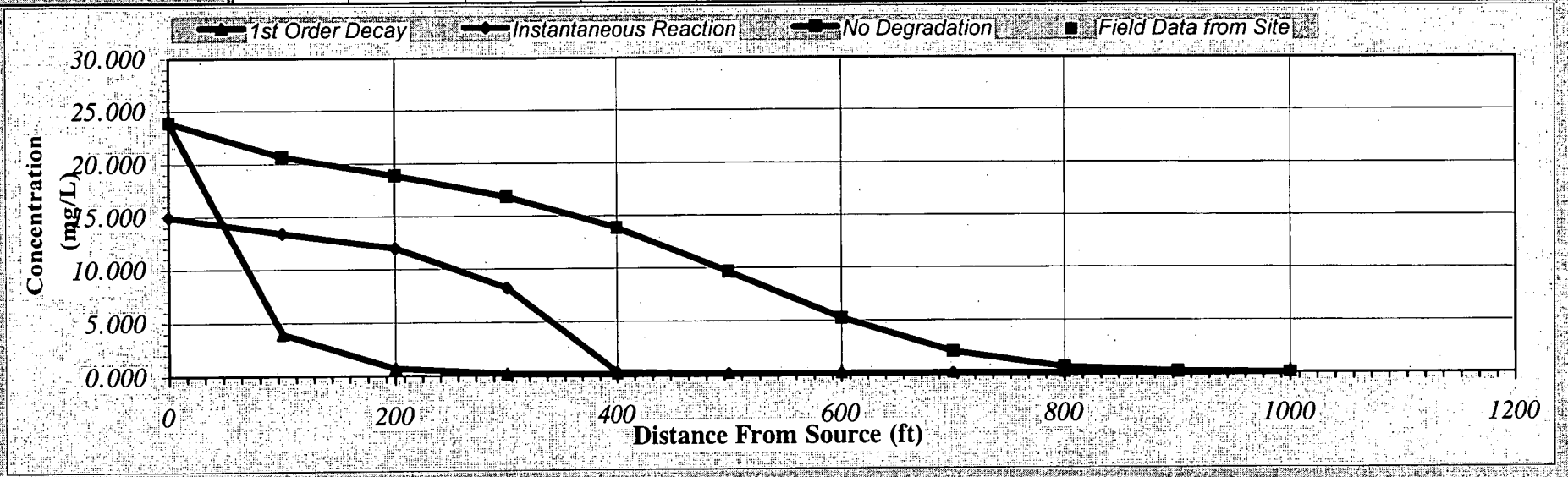
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	23.913	20.659	18.866	16.827	13.851	9.661	5.212	2.035	0.551	0.101	0.012
1st Order Decay	23.913	3.943	0.692	0.123	0.022	0.004	0.001	0.000	0.000	0.000	0.000
Inst. Reaction	14.939	13.406	11.978	8.210	0.190	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

6 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence

Version 1.4

NAS Brunswick
TPH-DRO Calibration
Run Name

Data Input Instructions:

1. Enter value directly... or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below).

Data used directly in model.
Value calculated by model. (Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	Vs	136.0	(ft/yr)
or		*or*	
Hydraulic Conductivity	K	6.3E-03	(cm/sec)
Hydraulic Gradient	I	0.0073	(ft/ft)
Porosity	n	0.35	(-)

2. DISPERSION

Longitudinal Dispersivity	alpha x	19.5	(ft)
Transverse Dispersivity*	alpha y	2.0	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		*or*	
Estimated Plume Length	Lp	600	(ft)

3. ADSORPTION

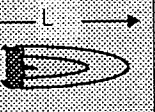
Retardation Factor*	R	2.1	(-)
or		*or*	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	38	(L/kg)
FractionOrganicCarbon	foc	5.7E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	7.5E-1	(per yr)
or		*or*	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	1.41	(mg/L)
Delta Nitrate*	NO3	8.67	(mg/L)
Observed Ferrous Iron*	Fe2+	0.45	(mg/L)
Delta Sulfate*	SO4	23.98	(mg/L)
Observed Methane*	CH4	5.19	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	6	(yr)



115	1. Enter value directly... or
or	2. Calculate by filling in grey
0.02	cells below. (To restore formulas, hit button below).
Variable*	*Data used directly in model.*
20	*Value calculated by model. (Don't enter any data)*

6. SOURCE DATA

Source Thickness in Sat Zone* 3 (ft)

Source Zones

Width* (ft)	Conc. (mg/L)*
25	0.5
30	2
20	20
30	2
25	0.5

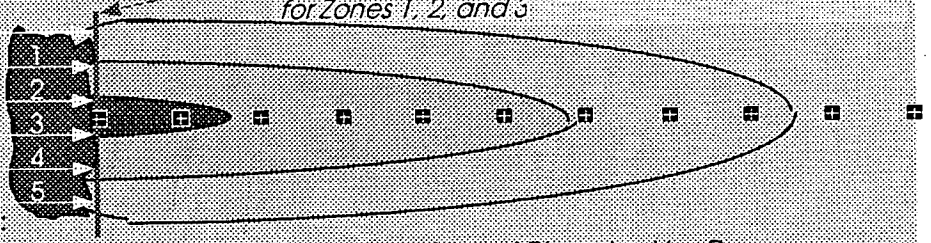
Source Halflife (see Help): 100 | 600 (yr)

Inst. React. | 1st Order

Soluble Mass 1800 (Kg)

In Source NAPL Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	0	100	200	300	400	500	600	700	800	900	1000
Concentration (mg/L)											

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — **View Output**

RUN ARRAY — **View Output**

Help

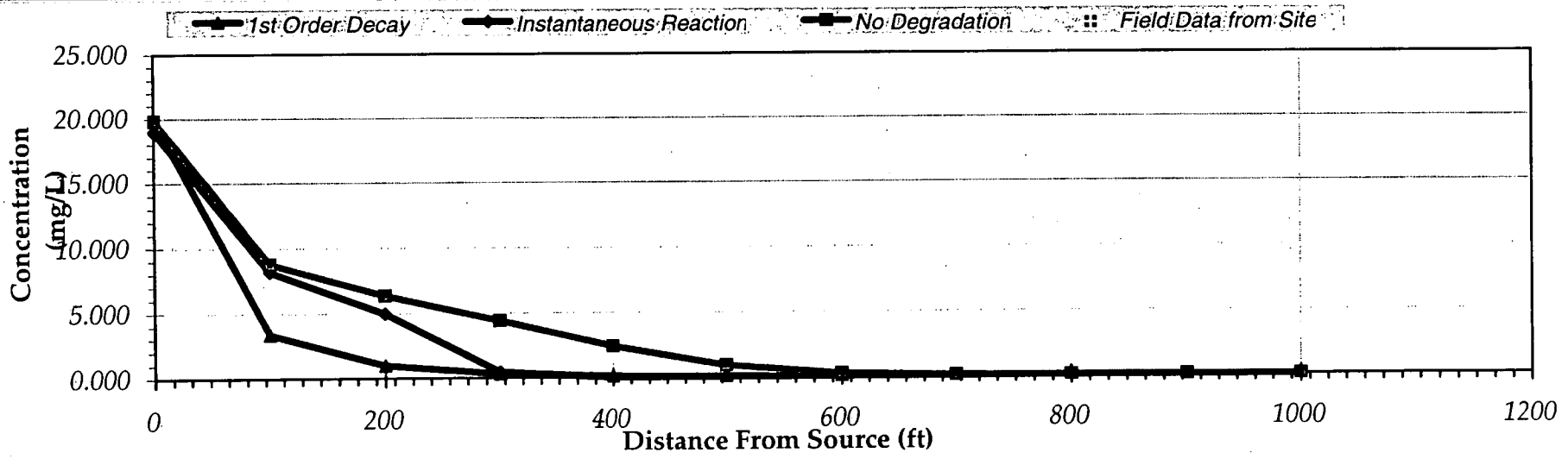
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No D gradation	19.854	8.771	6.350	4.401	2.379	0.862	0.190	0.024	0.002	0.000	0.000
1st Order Decay	19.854	3.358	0.971	0.304	0.091	0.022	0.004	0.000	0.000	0.000	0.000
Inst. Reaction	18.971	8.169	4.964	0.437	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Time: 6 Years

Return to Input

Recalculate This Sheet

Appendix B

BIOSCREEN TPH-GRO Data

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

NAS Brunswick
TPH-GRO East
Run Name

Data Input Instructions:

115 or 0.02 — *1. Enter value directly... or 2. Calculate by filling in grey cells below. (To restore formulas, hit button below)*

Variable* — *Data used directly in model.*

20 — *Value calculated by model. (Don't enter any data).*

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	136.0	*(ft/yr)*
or		or	
Hydraulic Conductivity	*K*	6.3E-03	*(cm/sec)*
Hydraulic Gradient	*I*	0.0073	*(ft/ft)*
Porosity	*n*	0.35	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	14.8	*(ft)*
Transverse Dispersivity*	*alpha y*	1.5	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		or	
Estimated Plume Length	*Lp*	340	*(ft)*

3. ADSORPTION

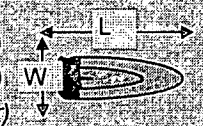
Retardation Factor*	*R*	1.5	*(-)*
or		or	
Soil Bulk Density	*rho*	1.7	*(kg/l)*
Partition Coefficient	*Koc*	38	*(L/kg)*
FractionOrganicCarbon	*foc*	5.7E-5	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	2.0E+0	*(per yr)*
or		or	
Solute Half-Life	*t-half*	1.00	*(year)*
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*	4.7	*(mg/L)*
Delta Nitrate*	*NO3*	28.9	*(mg/L)*
Observed Ferrous Iron*	*Fe2+*	1.5	*(mg/L)*
Delta Sulfate*	*SO4*	79.9	*(mg/L)*
Observed Methane*	*CH4*	17.7	*(mg/L)*

5. GENERAL

Modeled Area Length*	1000	*(ft)*
Modeled Area Width*	200	*(ft)*
Simulation Time*	10	*(yr)*



6. SOURCE DATA

Source Thickness in Sat Zone* 3 *(ft)*

Source Zones

Width* (ft)	Conc. (mg/L)*
25	0.5
30	5
20	20
30	5
25	0.5

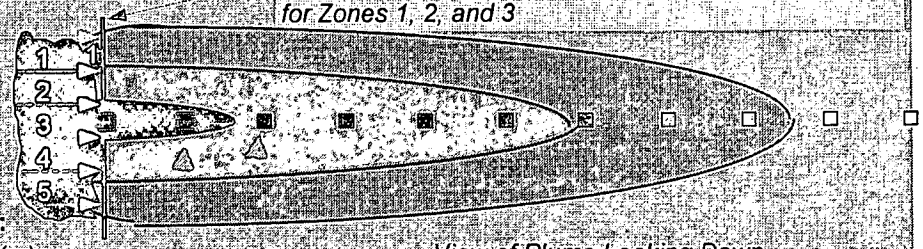
Source Halflife (see Help): 20 200 *(yr)*

Inst. React 1st Order

Soluble Mass 790 *(Kg)*

In Source NAPL Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
100	
200	
300	
400	
500	
600	
700	
800	
900	
1000	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

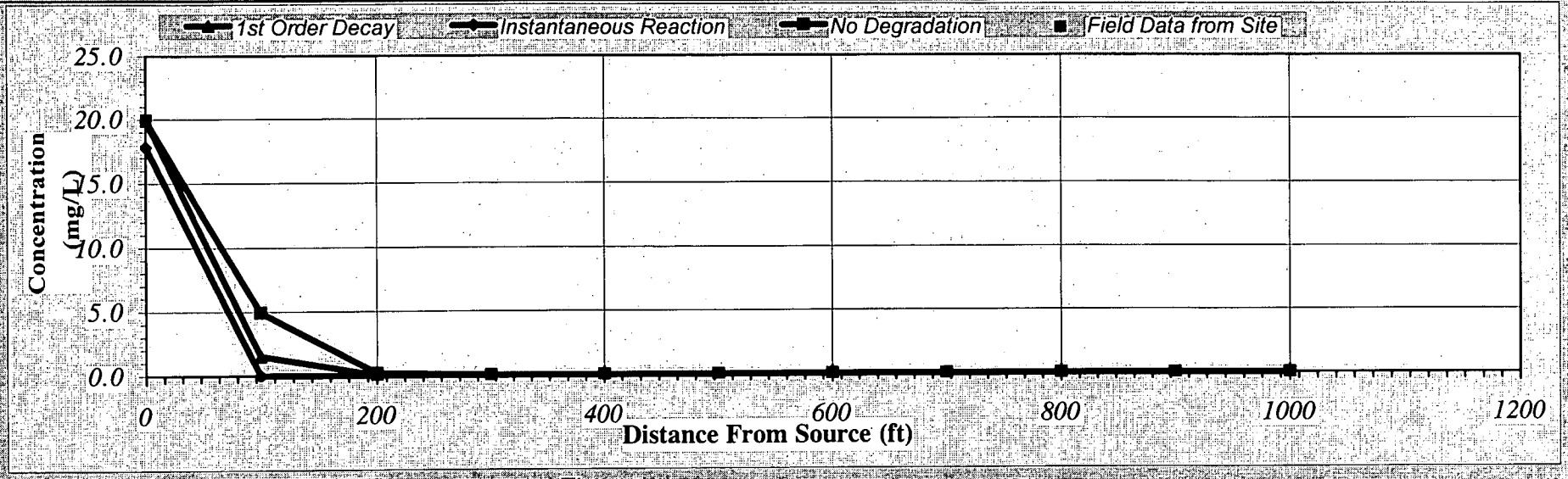
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.926	4.923	0.162	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1st Order Decay	19.926	1.527	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	17.825	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											

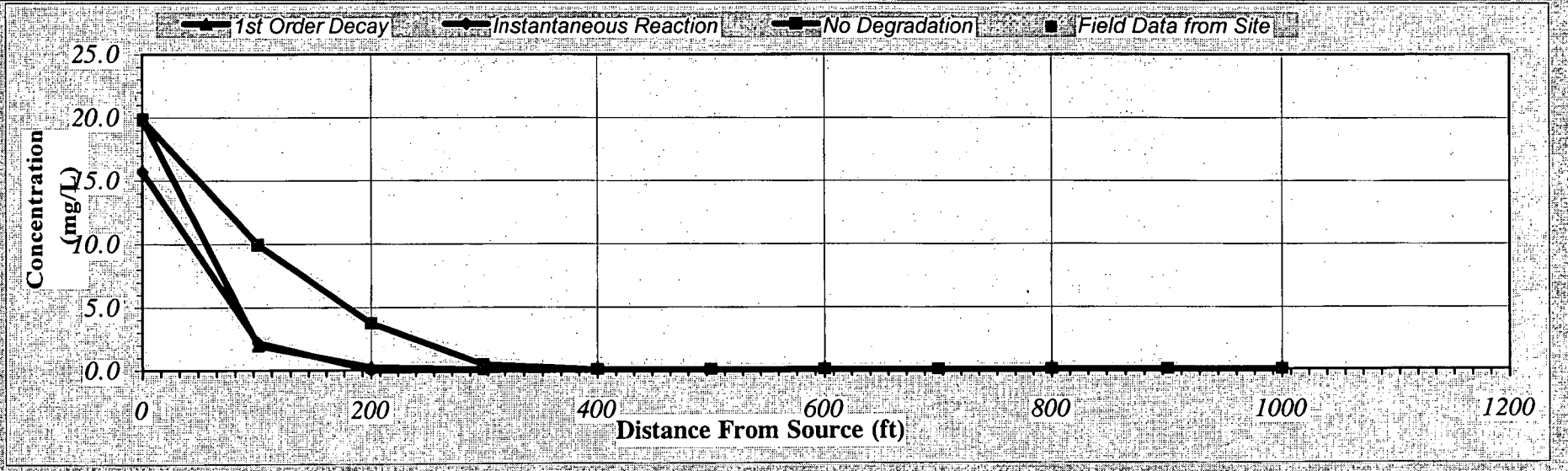


Time:
1 Years

Replay Animation | Next Timestep | Prev Timestep | Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.852	9.929	3.724	0.426	0.010	0.000	0.000	0.000	0.000	0.000	0.000
1st Order Decay	19.852	1.970	0.238	0.016	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	15.724	2.195	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



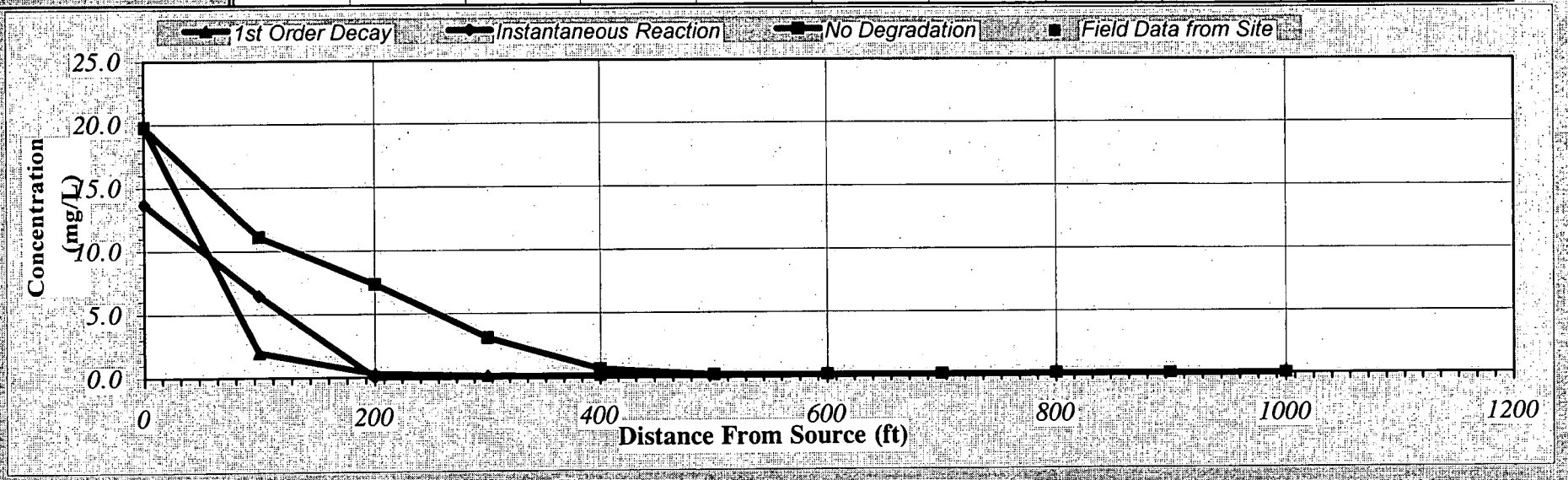
Replay Animation | Next Timestep | Prev Timestep

Time: 2 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.779	11.101	7.339	3.062	0.559	0.037	0.001	0.000	0.000	0.000	0.000
1st Order Decay	19.779	1.978	0.277	0.038	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	13.696	6.448	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



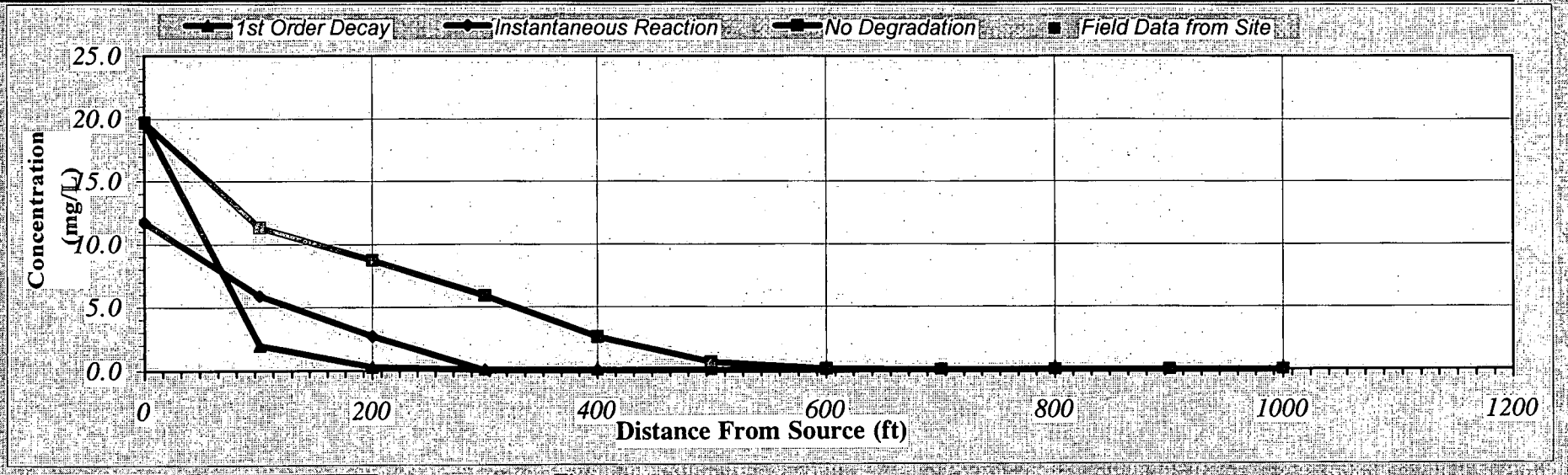
Replay Animation | Next Timestep | Prev Timestep

Time: 3 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.706	11.310	8.731	5.891	2.619	0.616	0.068	0.003	0.000	0.000	0.000
1st Order Decay	19.706	1.971	0.278	0.042	0.006	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	11.736	5.906	2.696	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Time:

4 Years

Replay Animation

Next Timestep

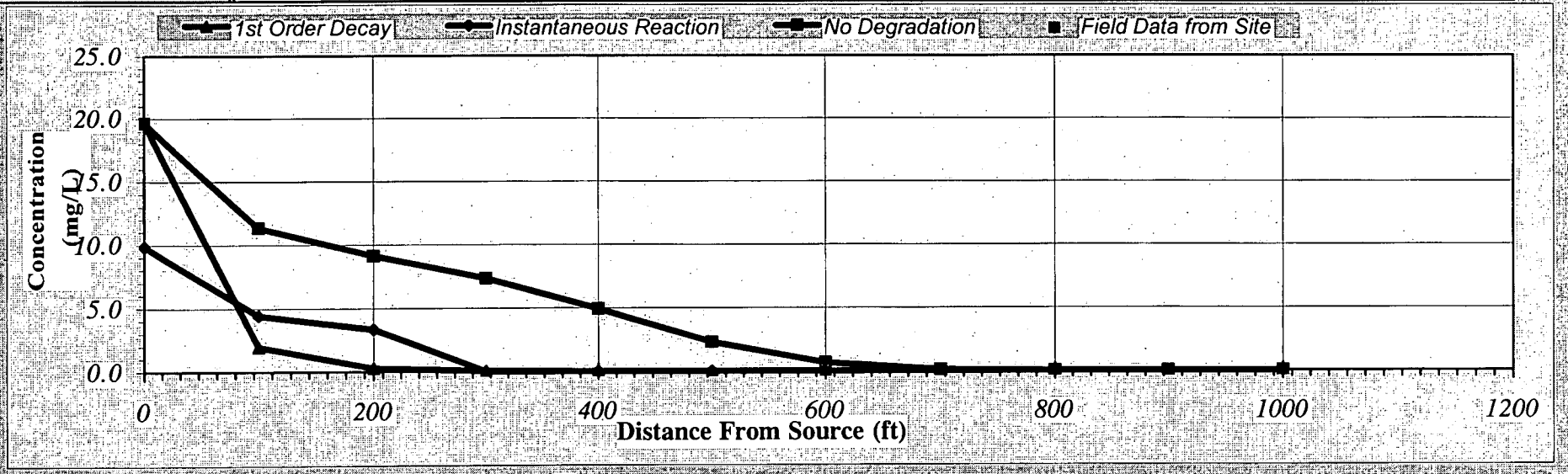
Prev Timestep

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.633	11.319	9.104	7.323	4.932	2.294	0.636	0.096	0.008	0.000	0.000
1st Order Decay	19.633	1.964	0.277	0.042	0.007	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	9.844	4.442	3.342	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



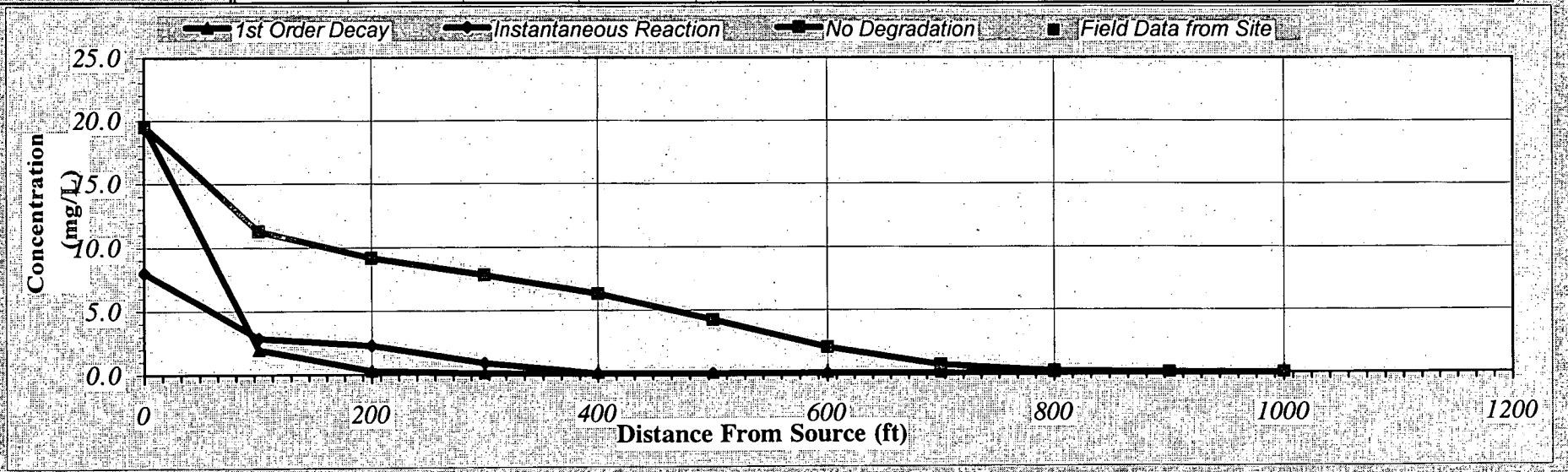
Replay Animation | Next Timestep | Prev Timestep

Time: 5 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.560	11.287	9.171	7.823	6.326	4.242	2.043	0.635	0.119	0.013	0.001
1st Order Decay	19.560	1.957	0.276	0.042	0.007	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	8.016	2.844	2.270	0.851	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



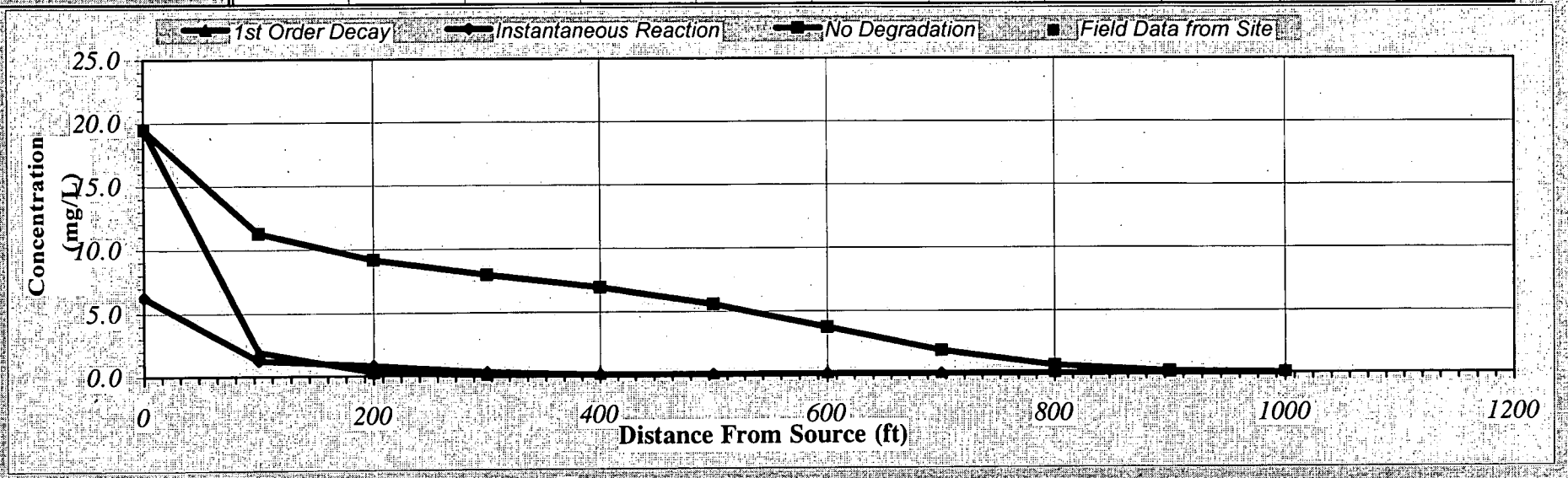
Replay Animation | Next Timestep | Prev Timestep

Time: 6 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.488	11.248	9.161	7.954	6.917	5.568	3.718	1.842	0.624	0.137	0.019
1st Order Decay	19.488	1.950	0.275	0.042	0.007	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	6.251	1.264	0.814	0.260	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



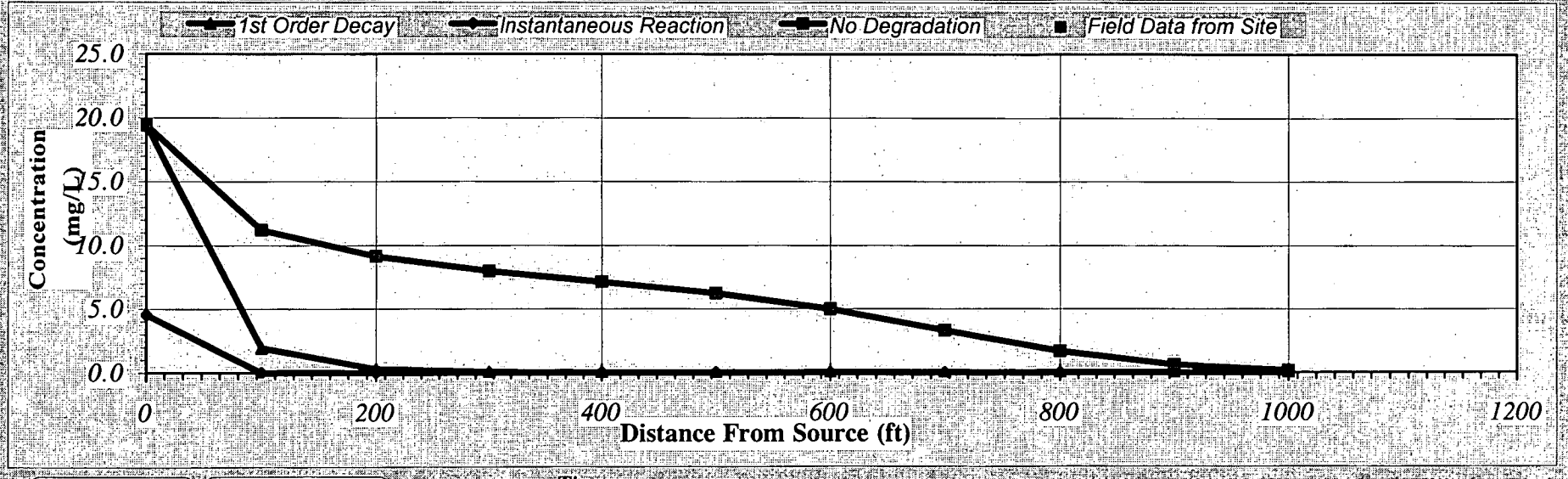
Replay Animation | Next Timestep | Prev Timestep

Time: 7 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.416	11.207	9.133	7.968	7.109	6.218	4.967	3.306	1.676	0.607	0.151
1st Order Decay	19.416	1.942	0.274	0.042	0.007	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	4.546	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



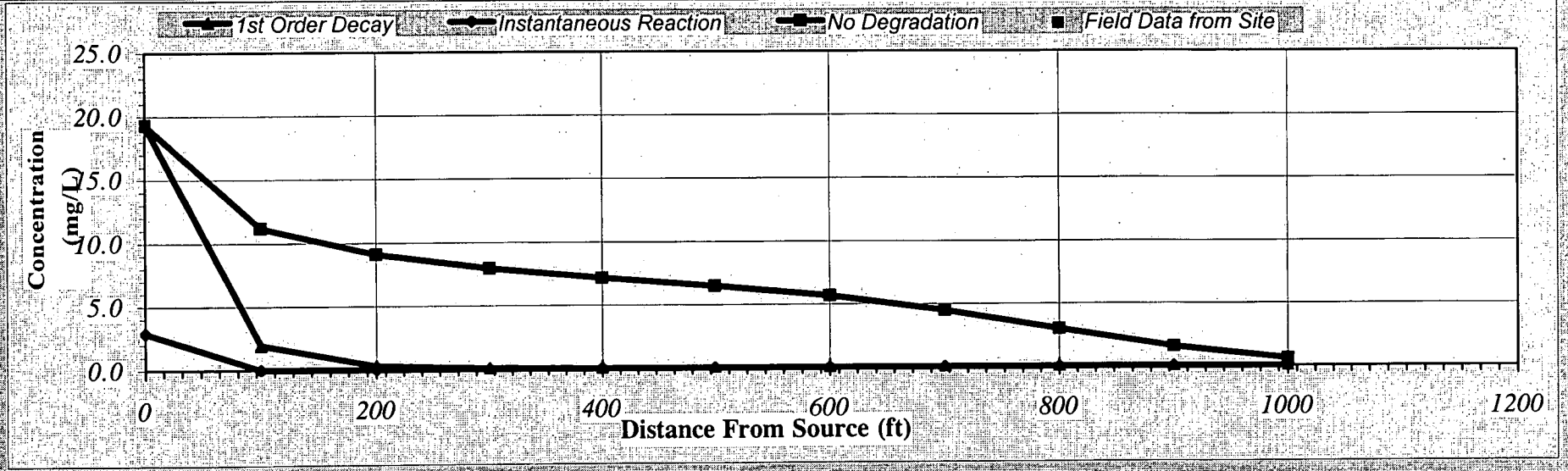
Replay Animation | Next Timestep | Prev Timestep

Time: 8 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.344	11.165	9.100	7.950	7.151	6.466	5.651	4.476	2.972	1.536	0.588
1st Order Decay	19.344	1.935	0.273	0.041	0.006	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	2.899	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



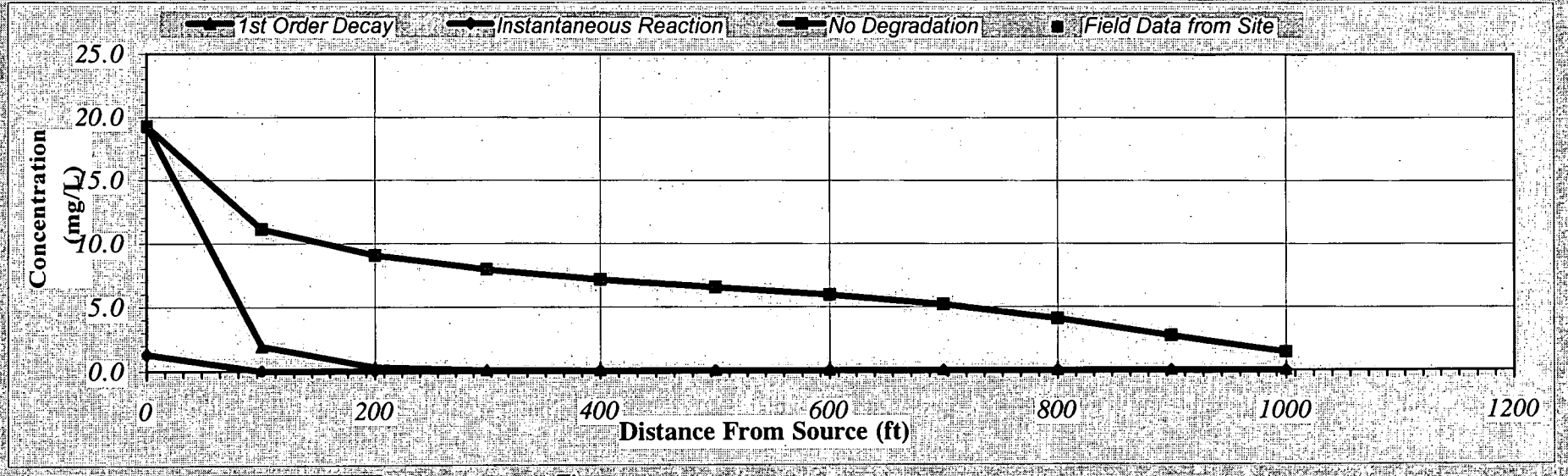
Replay Animation | Next Timestep | Prev Timestep

Time: 9 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	19.272	11.124	9.067	7.923	7.144	6.537	5.948	5.178	4.067	2.695	1.416
1st Order Decay	19.272	1.928	0.272	0.041	0.006	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	1.309	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



R play Animation

Next Timestep

Prev Timestep

Time: 10 Years

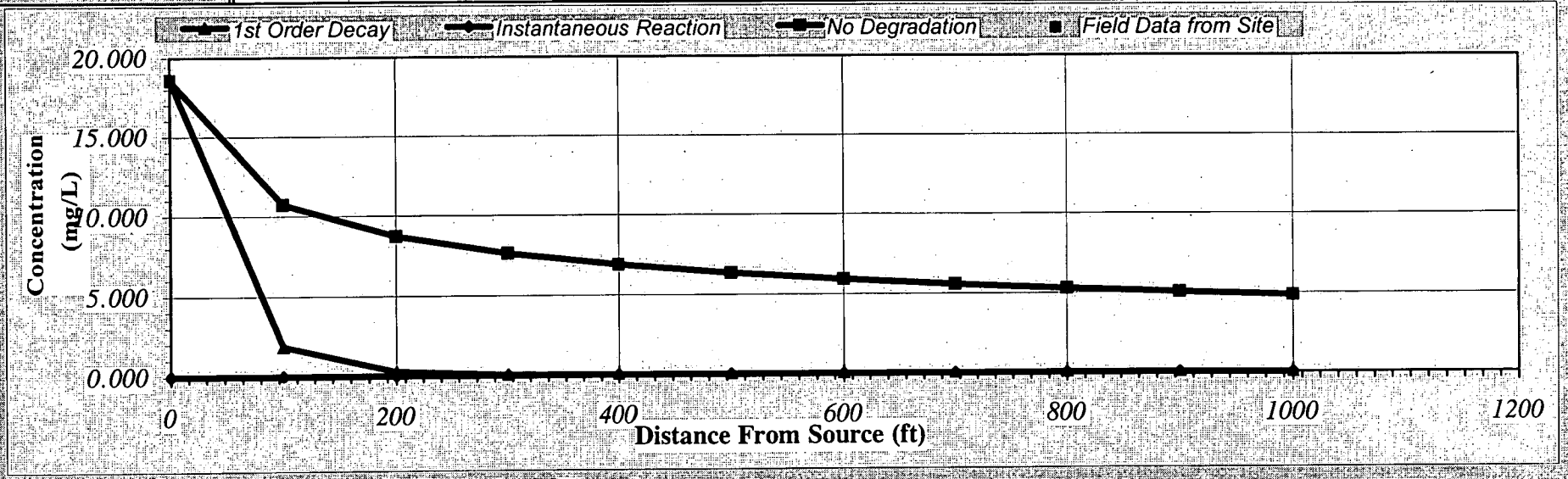
Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	18.571	10.719	8.737	7.636	6.891	6.341	5.913	5.567	5.281	5.038	4.829
1st Order Decay	18.571	1.858	0.262	0.040	0.006	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

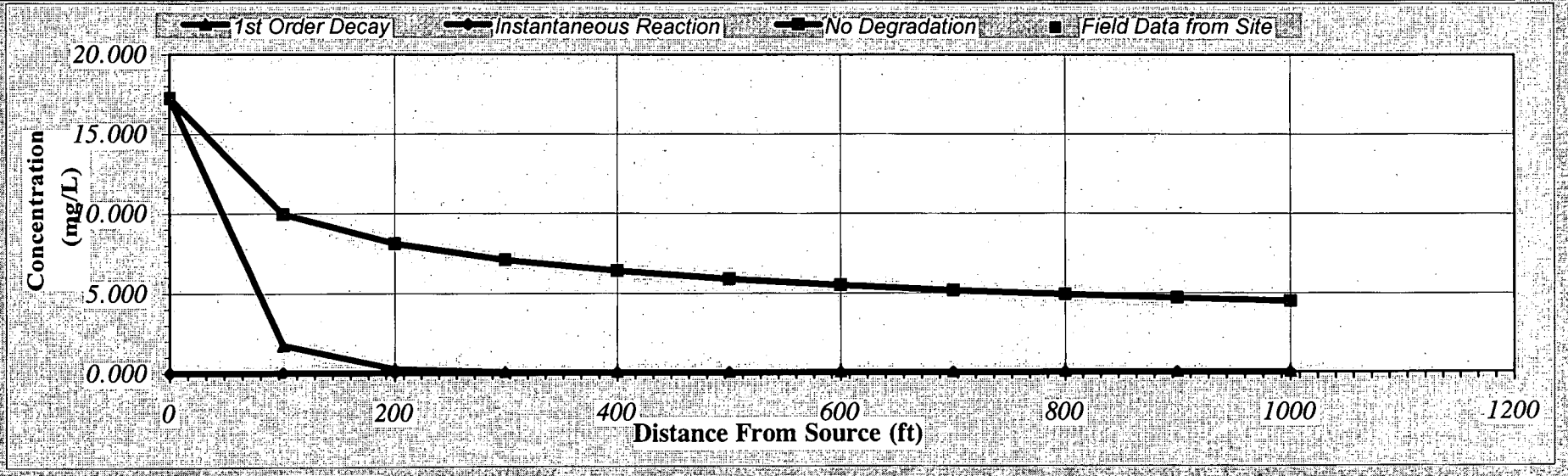
20 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	17.243	9.953	8.112	7.090	6.398	5.888	5.490	5.169	4.903	4.679	4.485
1st Order Decay	17.243	1.725	0.244	0.037	0.006	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

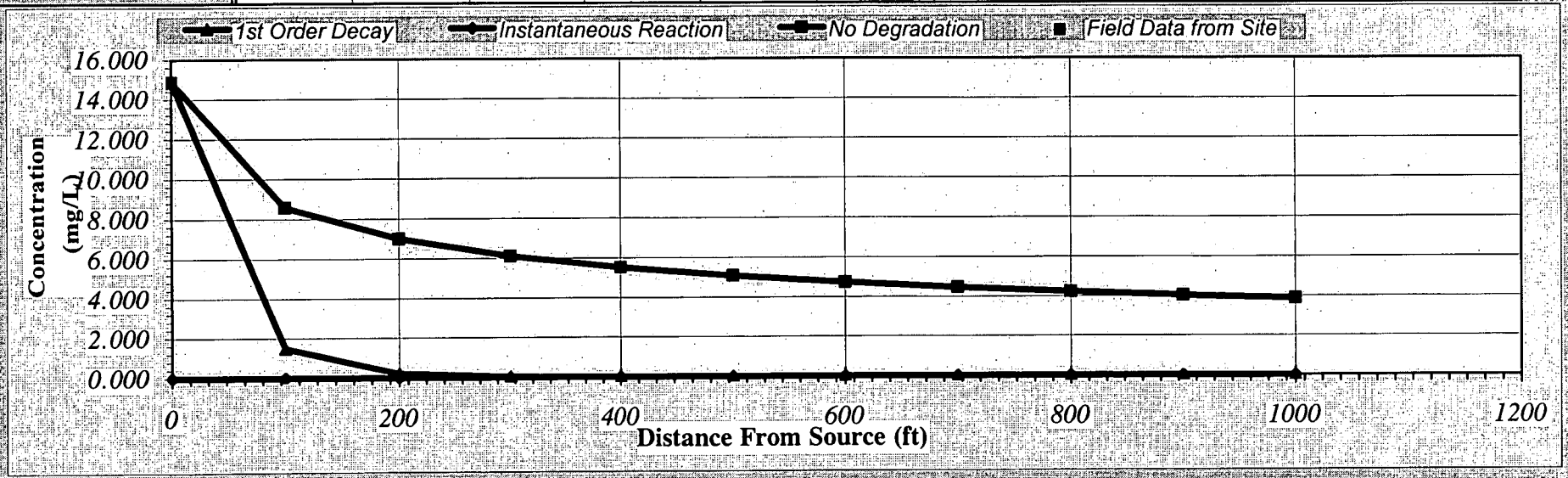
Time:
40 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	14.867	8.581	6.994	6.113	5.517	5.076	4.733	4.457	4.228	4.034	3.867
1st Order Decay	14.867	1.487	0.210	0.032	0.005	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

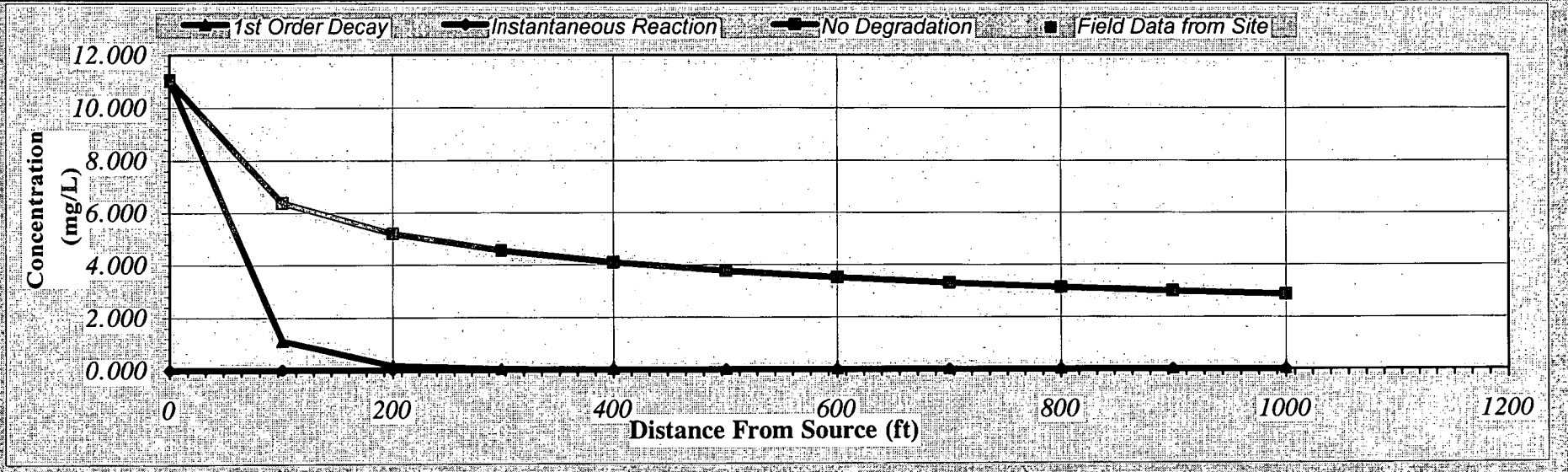
Time:
80 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	11.051	6.379	5.199	4.544	4.101	3.773	3.519	3.313	3.143	2.998	2.875
1st Order Decay	11.051	1.106	0.156	0.024	0.004	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

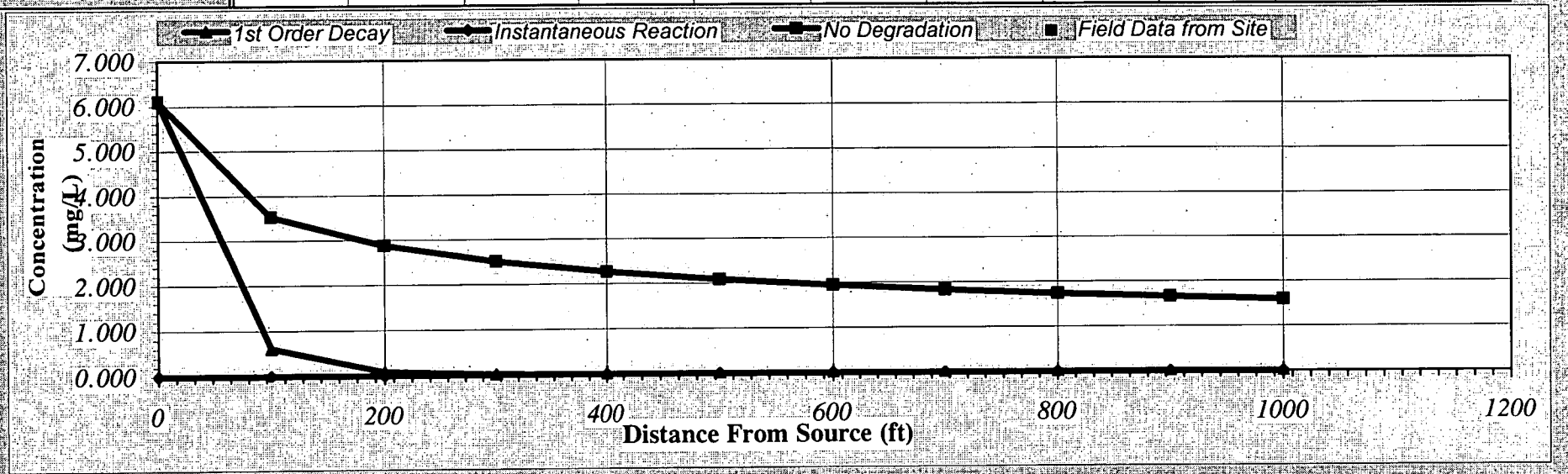
Time:
160 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	6.106	3.525	2.873	2.511	2.266	2.085	1.944	1.831	1.736	1.657	1.588
1st Order Decay	6.106	0.611	0.086	0.013	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

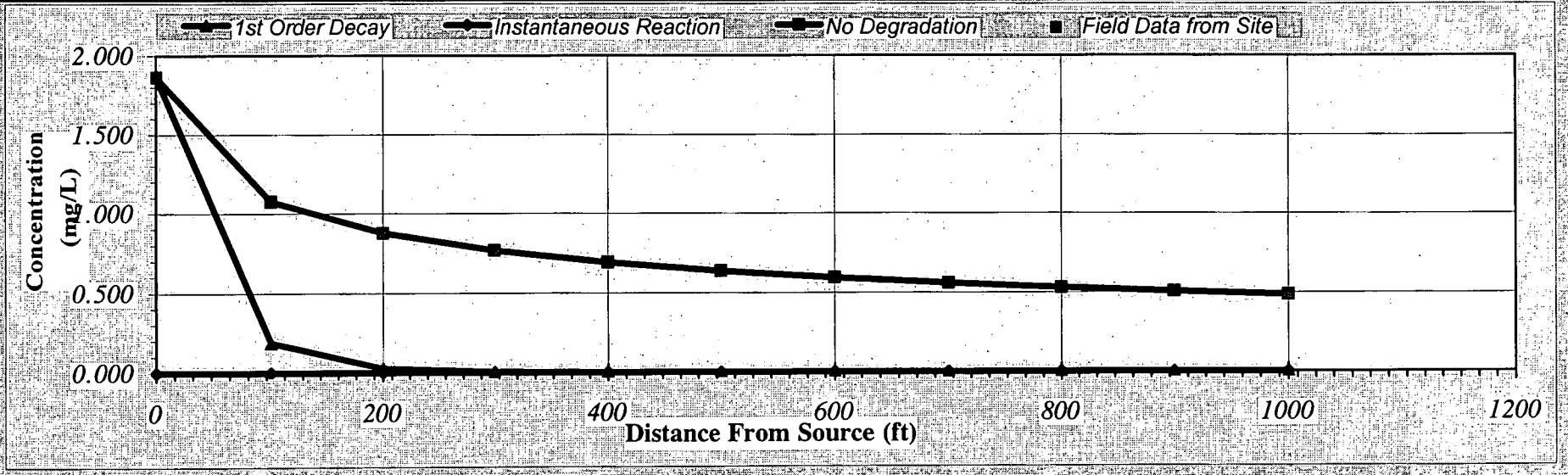
320 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.864	1.076	0.877	0.767	0.692	0.637	0.594	0.559	0.530	0.506	0.485
1st Order Decay	1.864	0.187	0.026	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

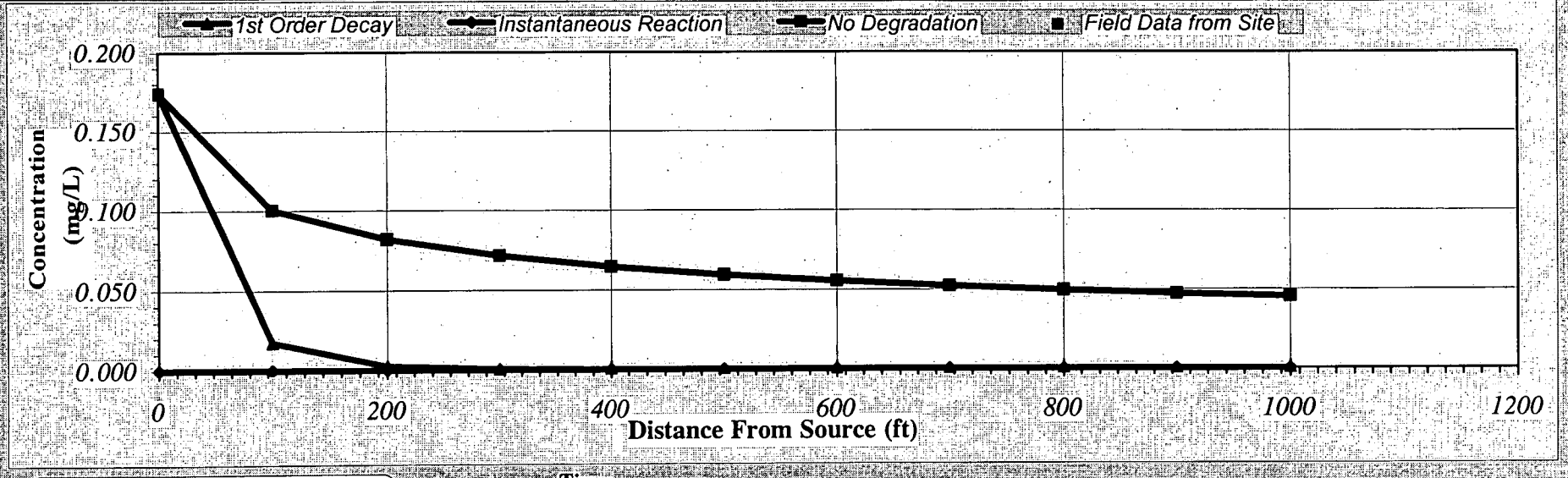
Time:
640 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.174	0.100	0.082	0.071	0.064	0.059	0.055	0.052	0.049	0.047	0.045
1st Order Decay	0.174	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

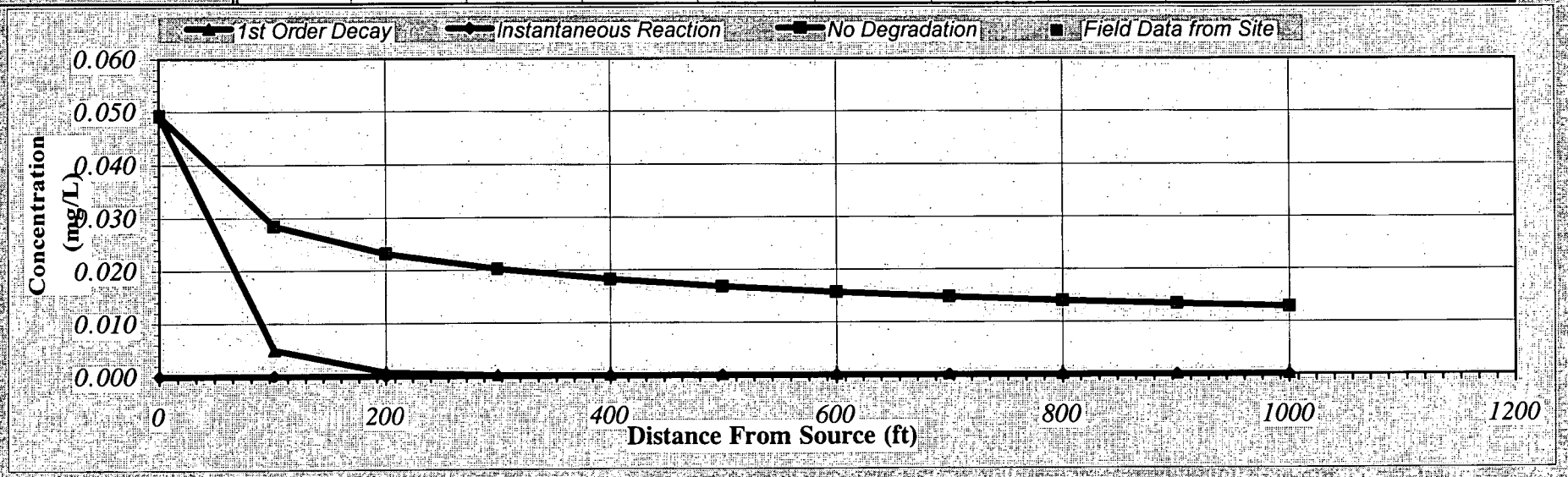
Time: 1,280 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.049	0.028	0.023	0.020	0.018	0.017	0.016	0.015	0.014	0.013	0.013
1st Order Decay	0.049	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

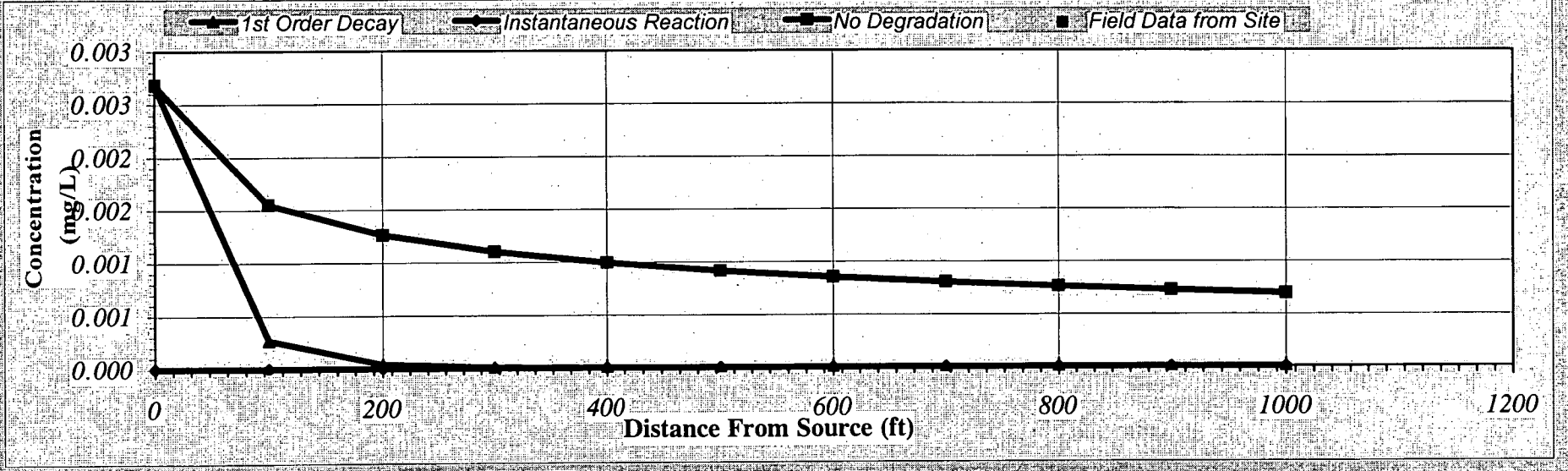
1,620 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
1st Order Decay	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

2,405 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

NAS Brunswick
TPH-GRO West
Run Name

Data Input Instructions:
115 ▸ 1. Enter value directly ... or
or ▸ 2. Calculate by filling in grey
0.02 cells below. (To restore formulas, hit button below)
Variable* ▸ Data used directly in model.
20 ▸ Value calculated by model. (Don't enter any data).

1. HYDROGEOLOGY

Seepage Velocity*	Vs	136.0	(ft/yr)
or		or	
Hydraulic Conductivity	K	6.3E-03	(cm/sec)
Hydraulic Gradient	i	0.0073	(ft/ft)
Porosity	n	0.35	(-)

2. DISPERSION

Longitudinal Dispersivity*	alpha x	13.6	(ft)
Transverse Dispersivity*	alpha y	1.4	(ft)
Vertical Dispersivity*	alpha z	0.0	(ft)
or		or	
Estimated Plume Length	Lp	290	(ft)

3. ADSORPTION

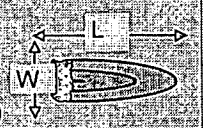
Retardation Factor*	R	1.5	(-)
or		or	
Soil Bulk Density	rho	1.7	(kg/l)
Partition Coefficient	Koc	38	(L/kg)
FractionOrganicCarbon	foc	5.7E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	lambda	2.0E+0	(per yr)
or		or	
Solute Half-Life	t-half	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	DO	4.7	(mg/L)
Delta Nitrate*	NO3	28.9	(mg/L)
Observed Ferrous Iron*	Fe2+	1.5	(mg/L)
Delta Sulfate*	SO4	79.9	(mg/L)
Observed Methane*	CH4	17.7	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	10	(yr)



6. SOURCE DATA

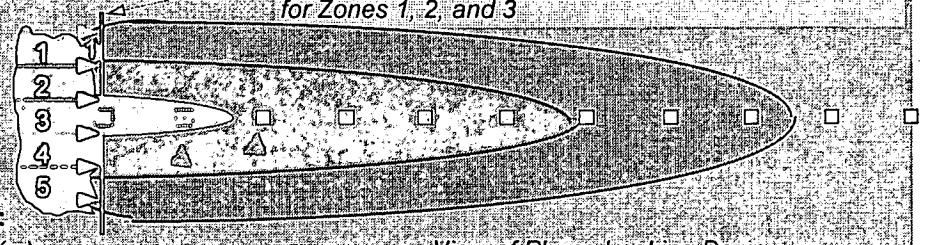
Source Thickness in Sat Zone* 3 (ft)

Source Zones

	Width* (ft)	Conc. (mg/L)*
1	35	0.5
2	40	2.5
3	20	10
4	40	2.5
5	35	0.5

Source Halflife (see Help):
30 (Inst. React) | 600 (1st Order) (yr)
Soluble Mass 1410 (Kg)
In Source NAPL Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
100	
200	
300	
400	
500	
600	
700	
800	
900	
1000	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

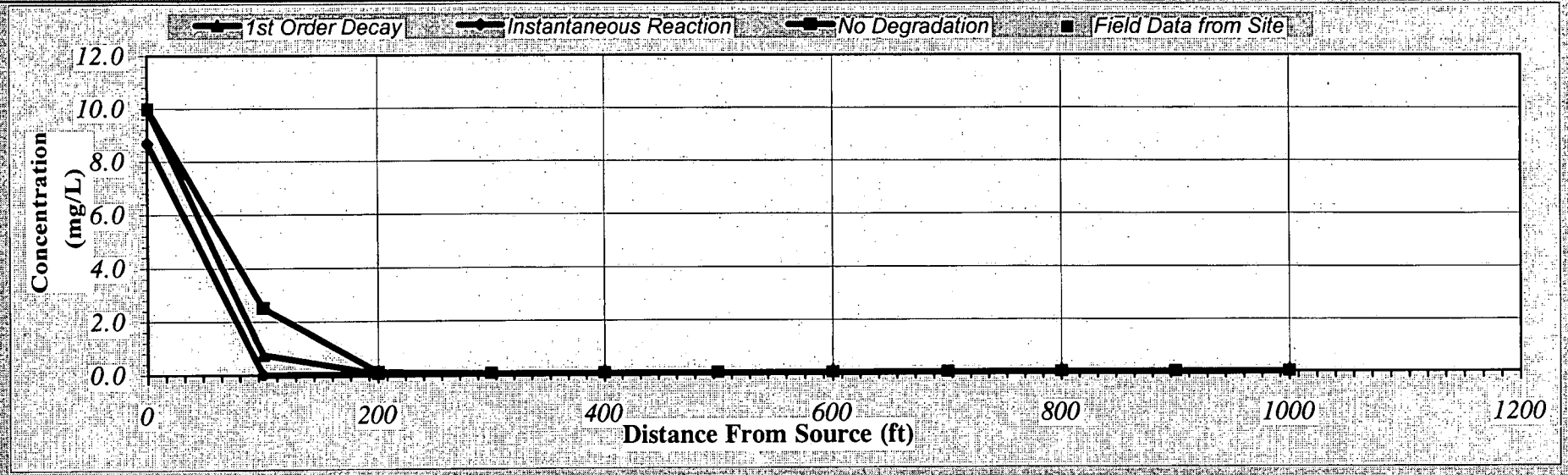
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.988	2.514	0.068	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1st Order Decay	9.988	0.756	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	8.678	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



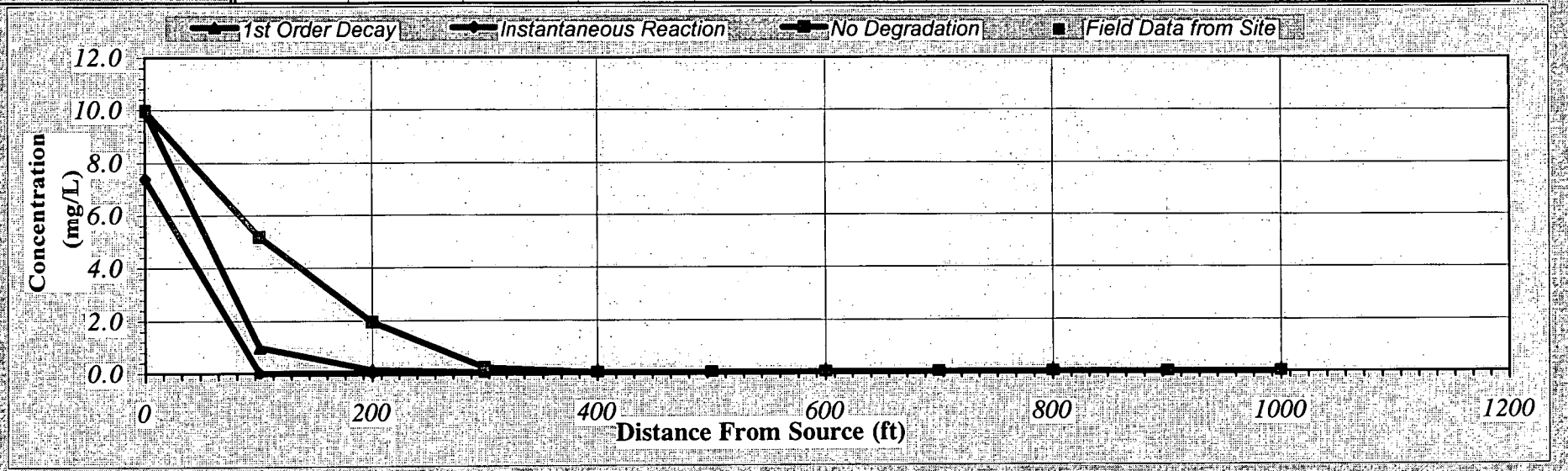
Time:

1 Years

Replay Animation | Next Timestep | Prev Timestep | Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.975	5.178	1.945	0.199	0.004	0.000	0.000	0.000	0.000	0.000	0.000
1st Order Decay	9.975	0.991	0.118	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	7.388	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



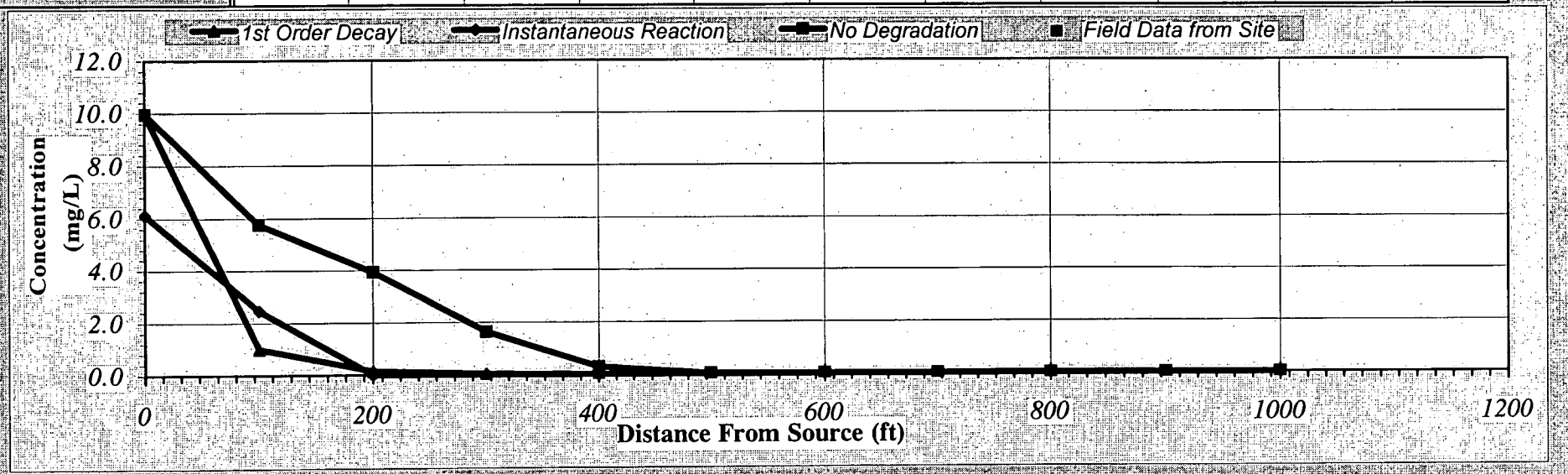
Replay Animation | Next Timestep | Prev Timestep

Time: 2 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.963	5.766	3.930	1.633	0.274	0.015	0.000	0.000	0.000	0.000	0.000
1st Order Decay	9.963	0.997	0.139	0.019	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	6.128	2.461	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



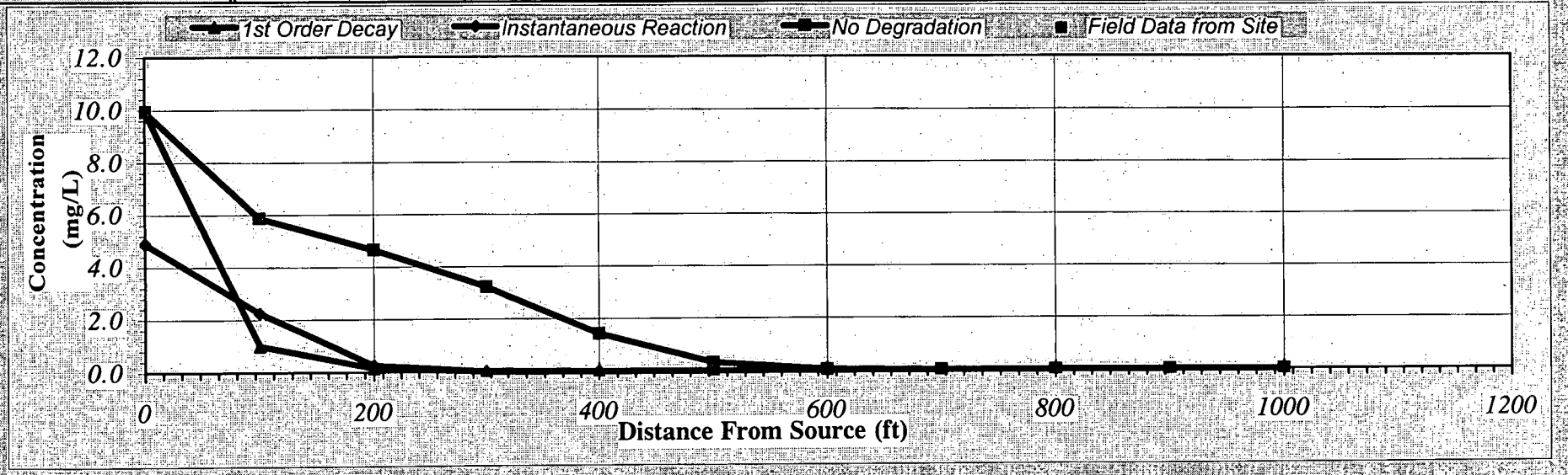
Replay Animation | Next Timestep | Prev Timestep

Time: 3 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.950	5.869	4.665	3.228	1.420	0.311	0.029	0.001	0.000	0.000	0.000
1st Order Decay	9.950	0.996	0.140	0.021	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	4.898	2.244	0.243	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Replay Animation

Next Timestep

Prev Timestep

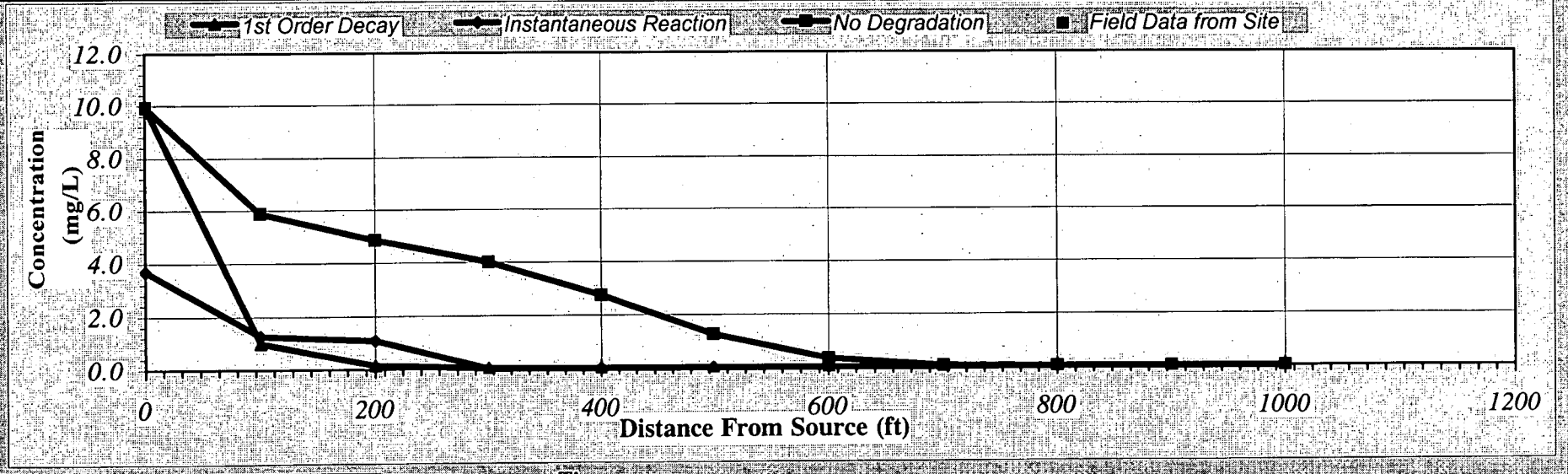
Time: 4 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.938	5.881	4.853	4.016	2.750	1.260	0.327	0.044	0.003	0.000	0.000
1st Order Decay	9.938	0.995	0.140	0.021	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	3.698	1.270	1.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



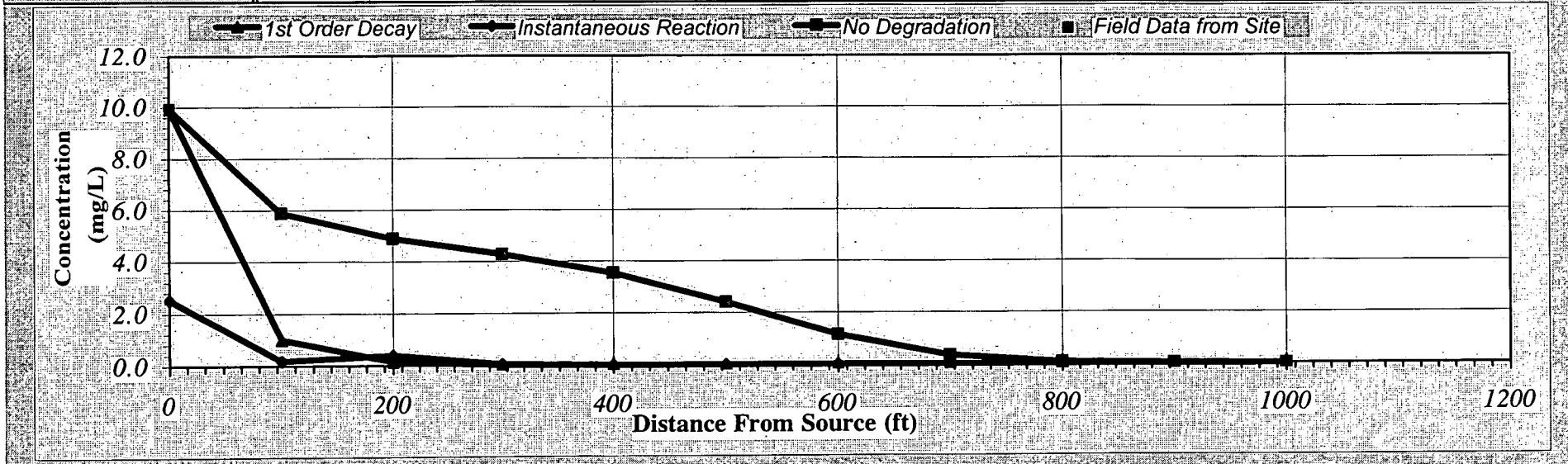
Replay Animation | Next Timestep | Prev Timestep

Time: 5 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.925	5.877	4.891	4.279	3.540	2.397	1.133	0.331	0.056	0.005	0.000
1st Order Decay	9.925	0.994	0.140	0.021	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	2.527	0.185	0.393	0.038	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



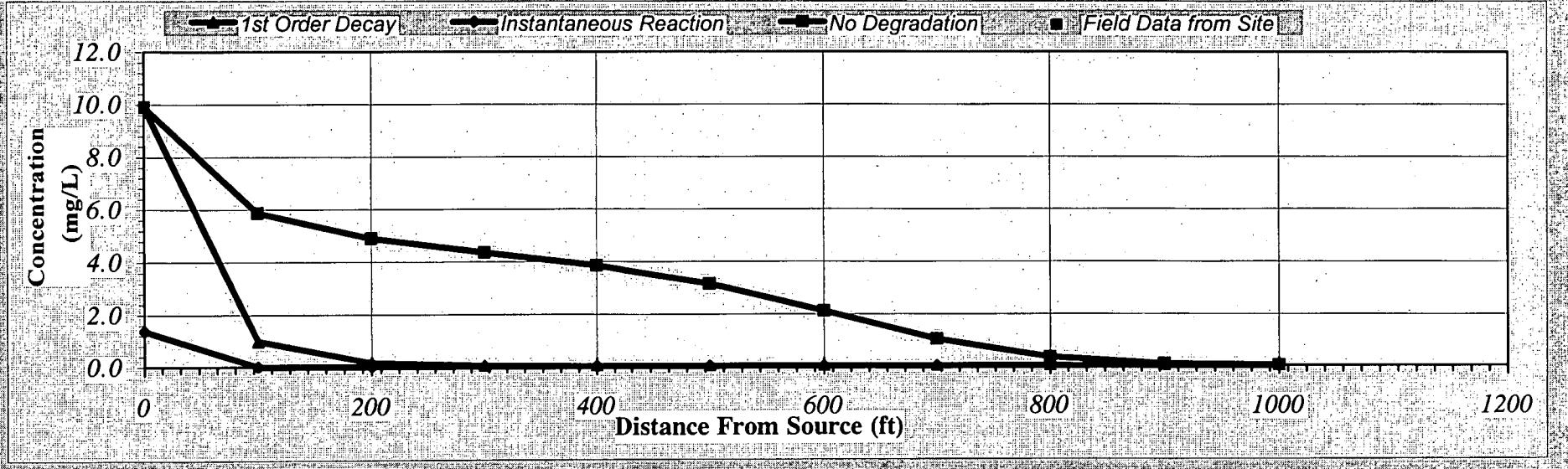
Replay Animation | Next Timestep | Prev Timestep

Time: 6 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.913	5.871	4.894	4.348	3.862	3.165	2.122	1.029	0.329	0.065	0.008
1st Order Decay	9.913	0.993	0.140	0.021	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	1.383	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Replay Animation

Next Timestep

Prev Timestep

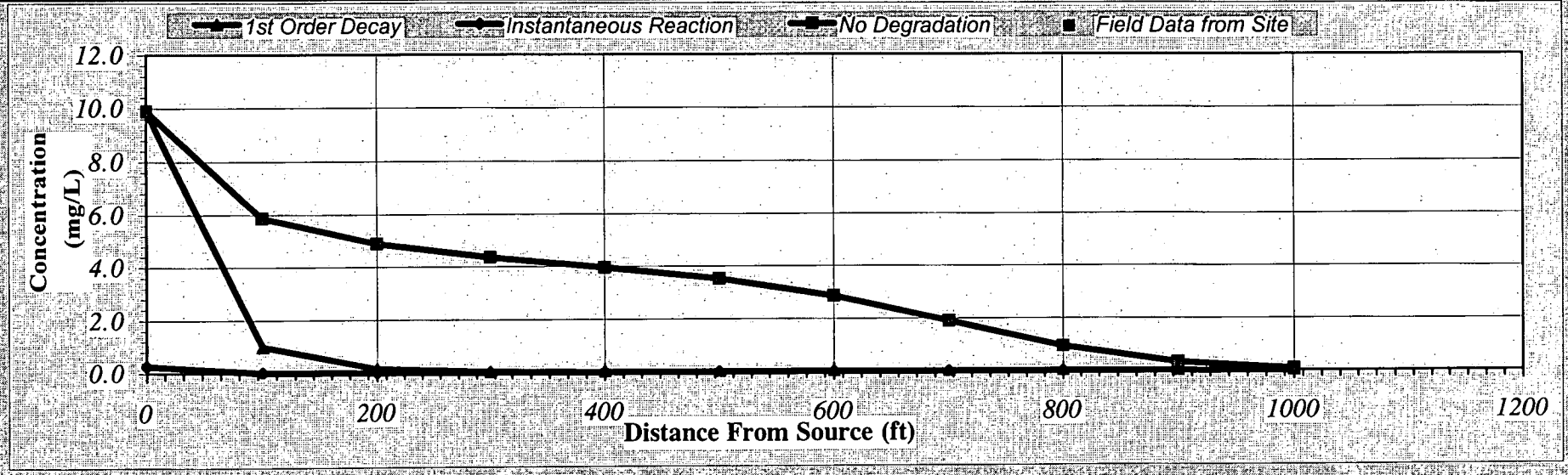
Time: 7 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.901	5.863	4.890	4.361	3.964	3.528	2.857	1.901	0.941	0.323	0.073
1st Order Decay	9.901	0.991	0.140	0.021	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.267	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



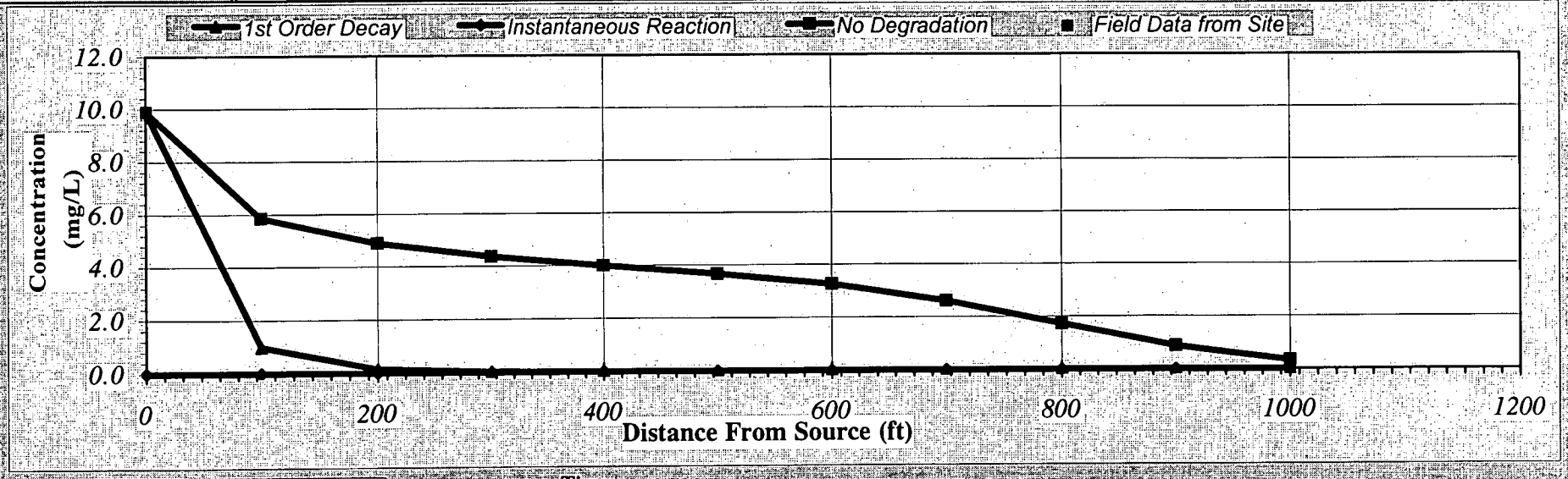
Replay Animation | Next Timestep | Prev Timestep

Time: 8 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.888	5.856	4.884	4.360	3.990	3.663	3.249	2.599	1.719	0.867	0.315
1st Order Decay	9.888	0.990	0.140	0.021	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



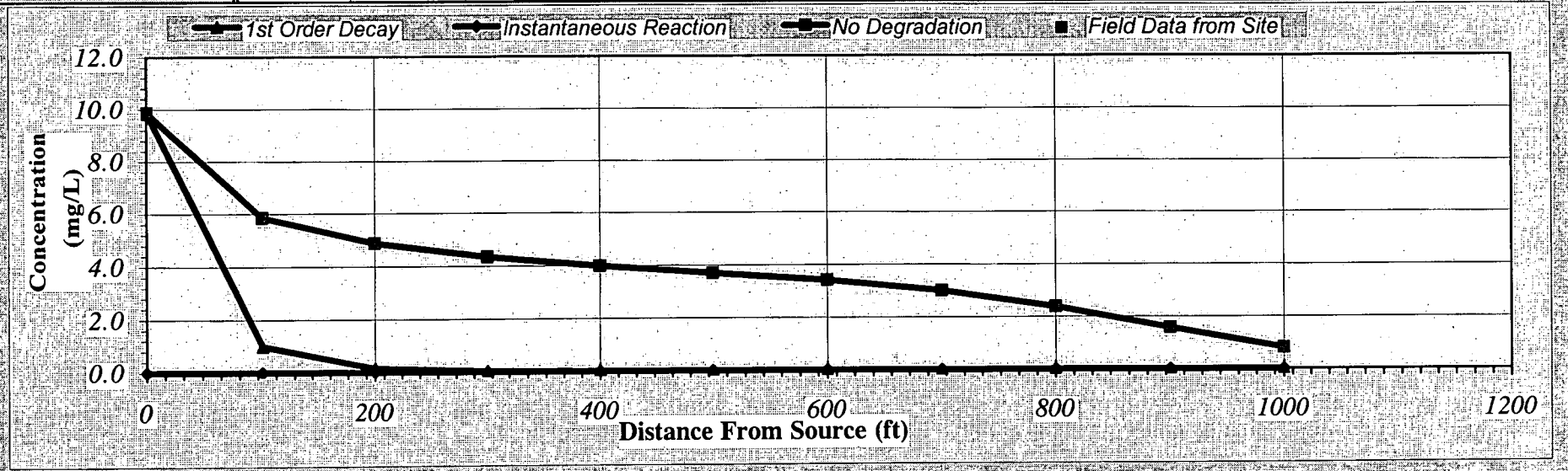
Replay Animation | Next Timestep | Prev Timestep

Time: 9 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.876	5.849	4.878	4.355	3.993	3.704	3.414	3.008	2.379	1.566	0.802
1st Order Decay	9.876	0.989	0.139	0.021	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



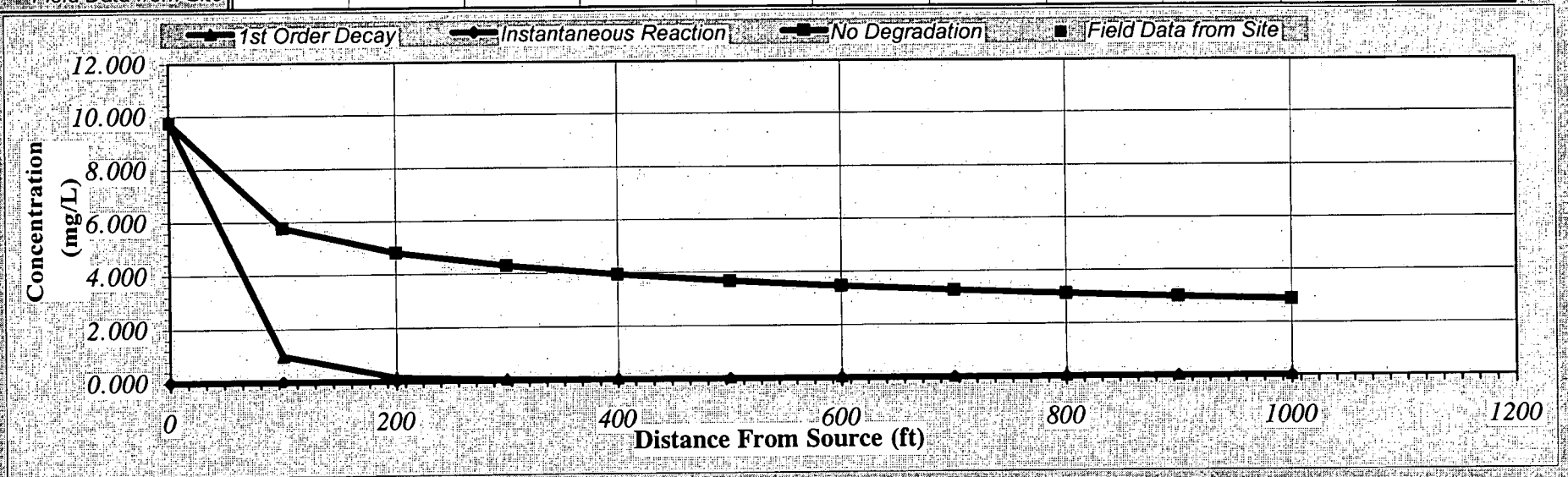
Replay Animation | Next Timestep | Prev Timestep

Time: 10 Years

Return to Input | Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.754	5.776	4.818	4.302	3.946	3.676	3.460	3.280	3.128	2.997	2.881
1st Order Decay	9.754	0.977	0.138	0.021	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

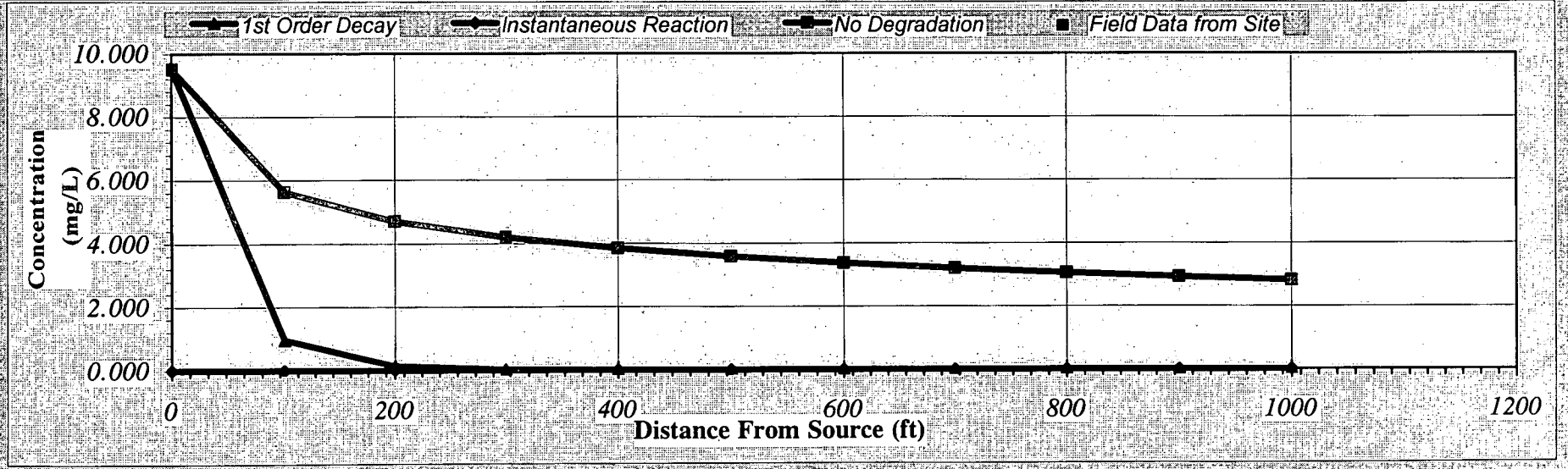
20 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.514	5.634	4.699	4.196	3.849	3.586	3.374	3.200	3.051	2.923	2.811
1st Order Decay	9.514	0.953	0.134	0.020	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

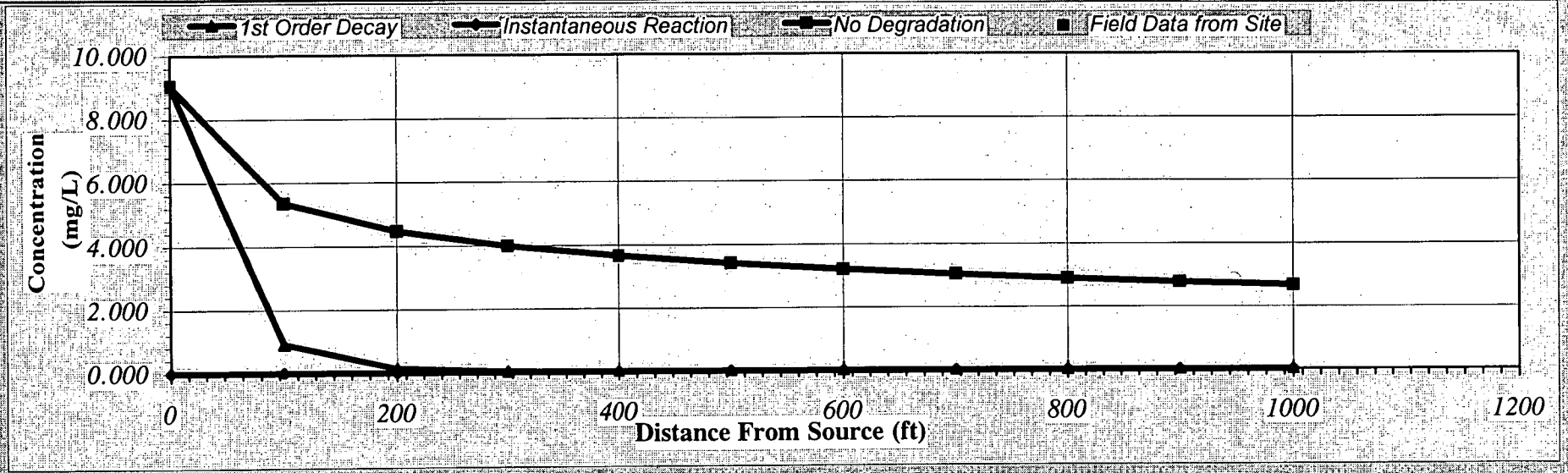
Time:
40 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.051	5.360	4.471	3.992	3.662	3.411	3.210	3.044	2.903	2.781	2.674
1st Order Decay	9.051	0.906	0.128	0.019	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

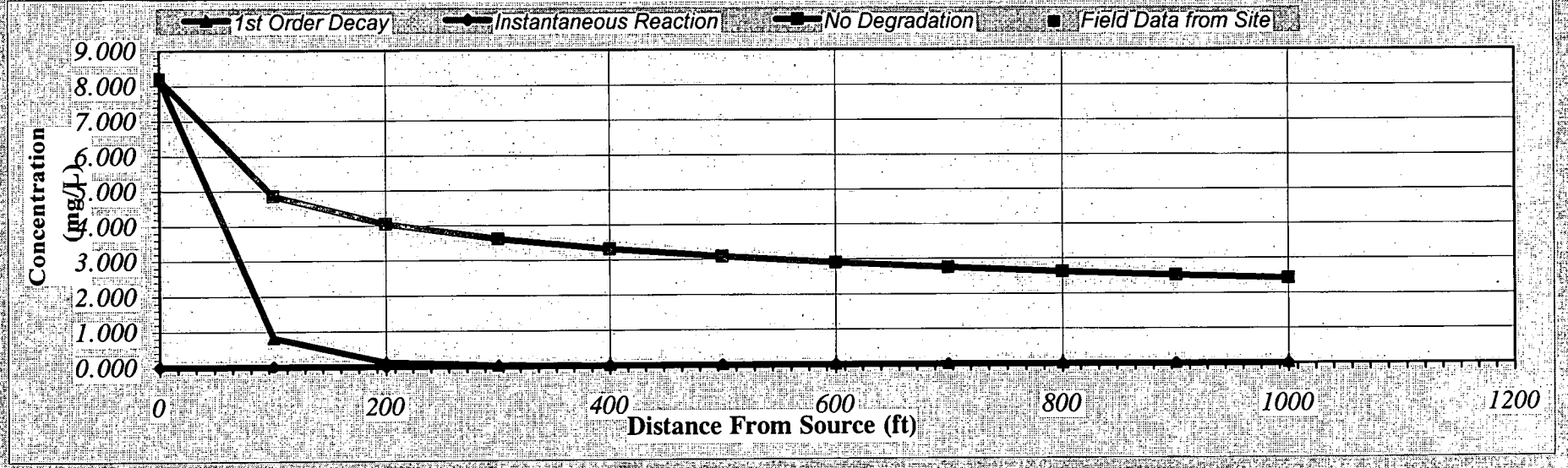
Time:
80 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	8.192	4.852	4.046	3.613	3.314	3.087	2.906	2.755	2.627	2.517	2.420
1st Order Decay	8.192	0.820	0.116	0.017	0.003	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

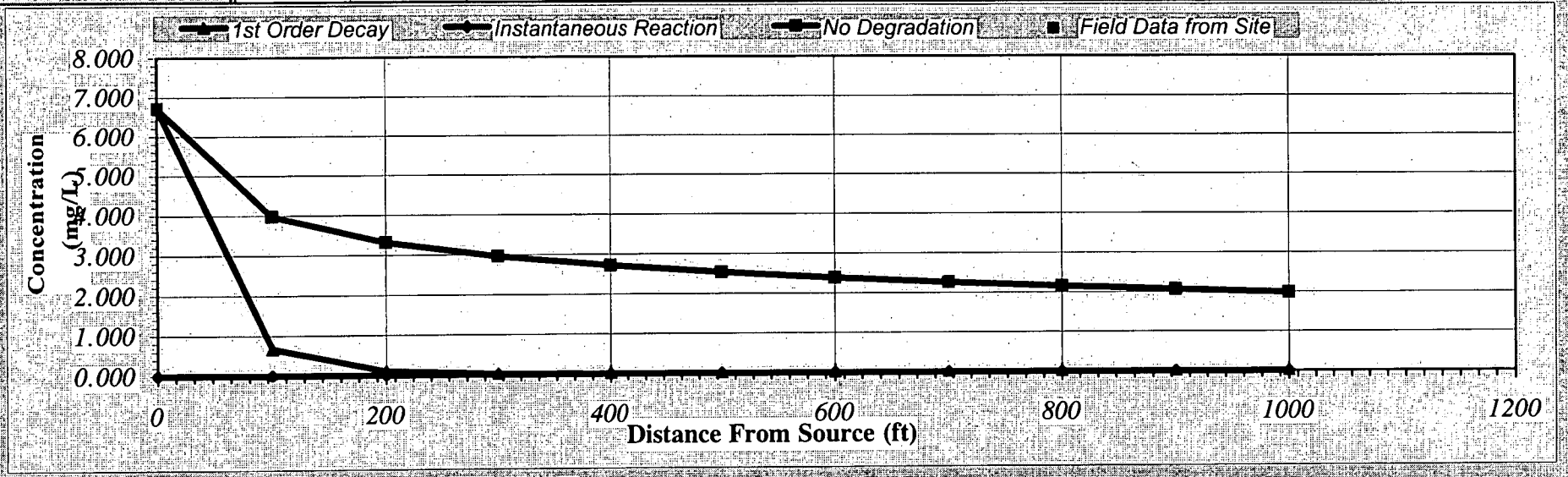
Time:
160 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	6.711	3.974	3.315	2.960	2.715	2.529	2.380	2.257	2.152	2.062	1.983
1st Order Decay	6.711	0.672	0.095	0.014	0.002	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

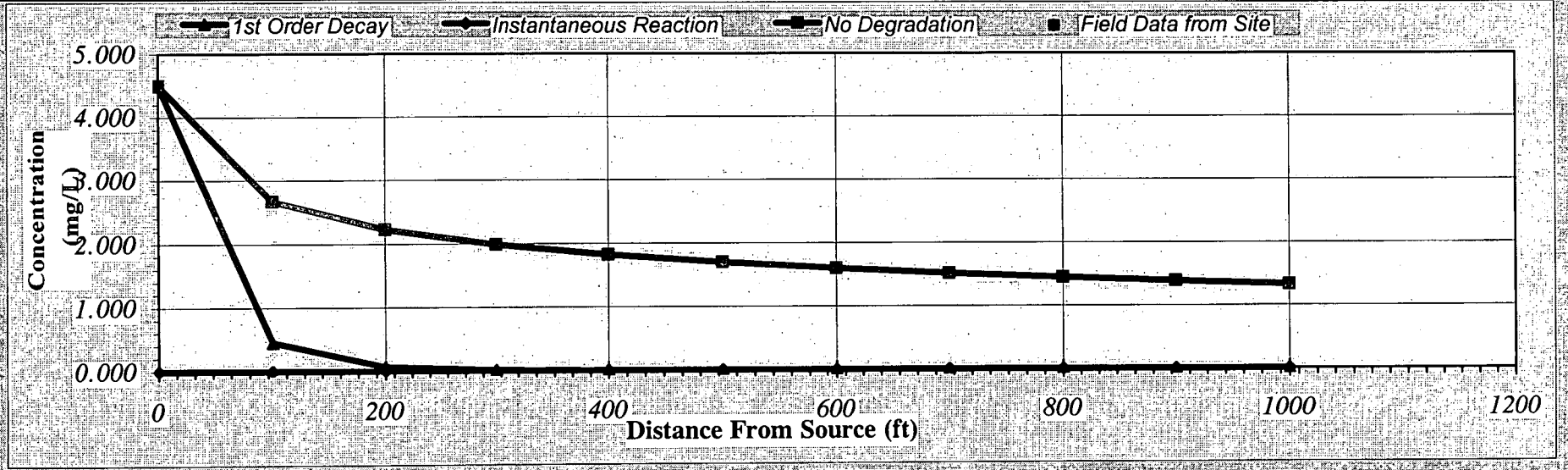
Time:
320 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	4.504	2.667	2.225	1.986	1.822	1.697	1.598	1.515	1.444	1.384	1.331
1st Order Decay	4.504	0.451	0.064	0.010	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

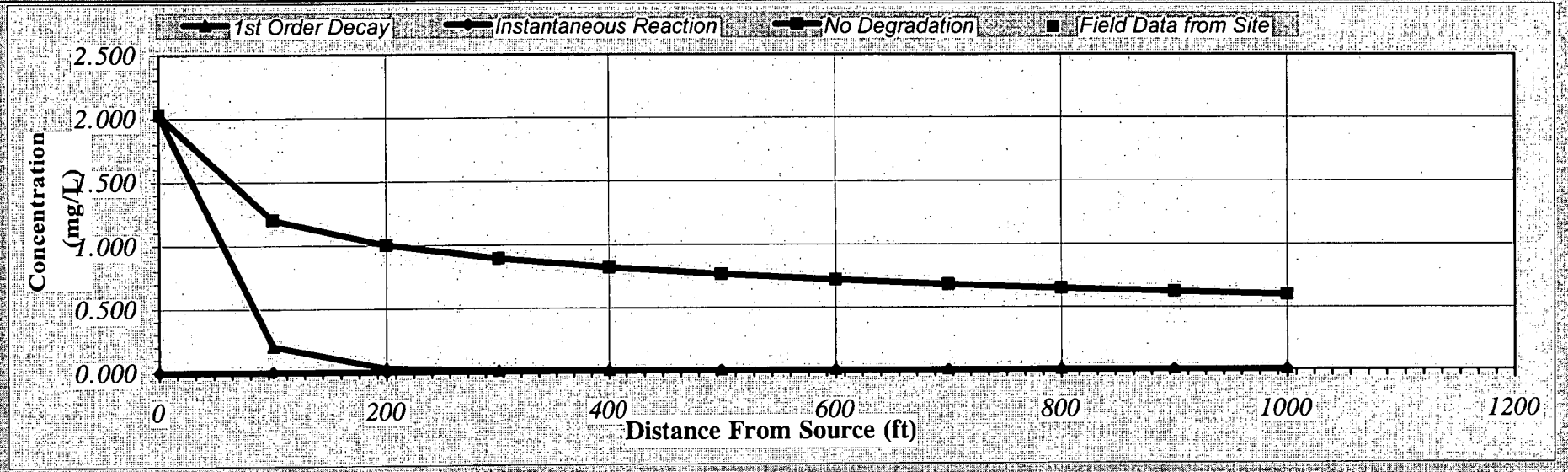
Time:
640 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	2.028	1.201	1.002	0.895	0.821	0.764	0.719	0.682	0.651	0.623	0.599
1st Order Decay	2.028	0.203	0.029	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Time: 1,280 Years

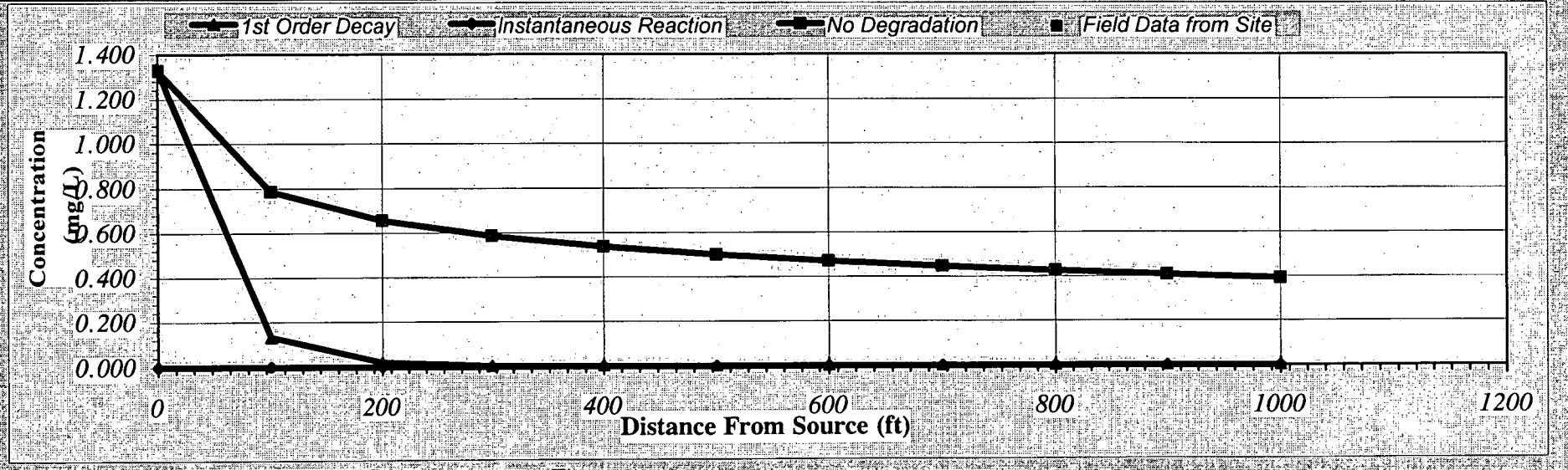
Calculate Animation
Next Timestep
Prev Timestep

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.328	0.786	0.656	0.586	0.537	0.500	0.471	0.447	0.426	0.408	0.392
1st Order Decay	1.328	0.133	0.019	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

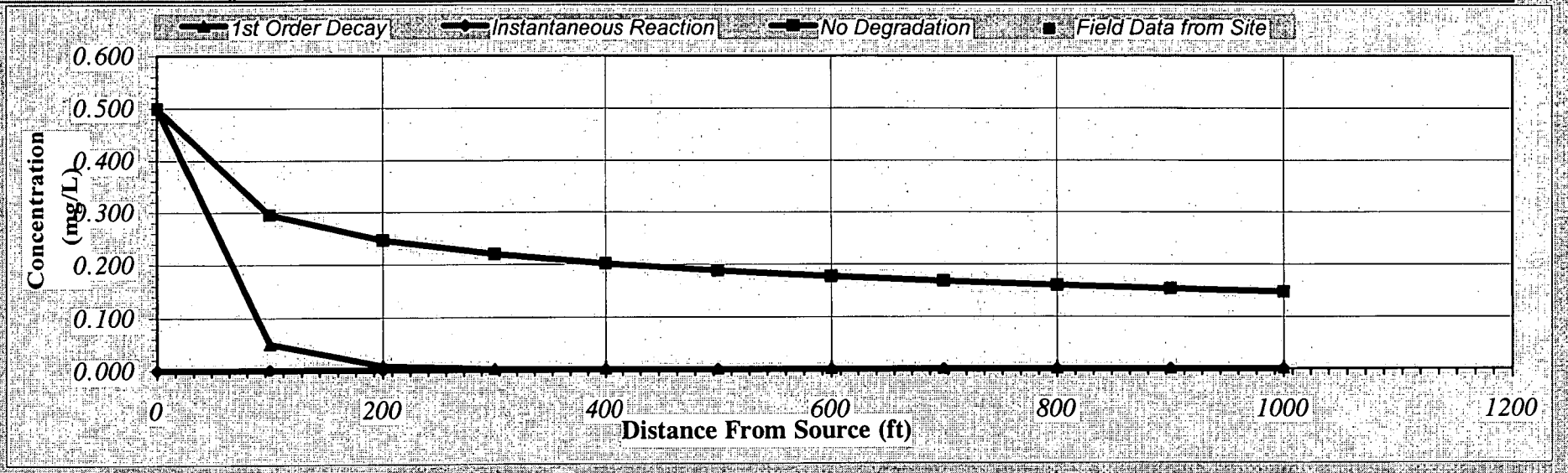
Time:
1,620 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL:	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.499	0.296	0.247	0.220	0.202	0.188	0.177	0.168	0.160	0.153	0.147
1st Order Decay	0.499	0.050	0.007	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation: Next Timestep / Prev Timestep

Time: 2,405 Years

Return to Input

Recalculate This Sheet

Appendix C

BIOSCREEN TPH-DRO Data

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

NAS Brunswick
DRO-East Prediction
Run Name

Data Input Instructions:
1. Enter value directly ...or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below)

Variable* ▸ *Data used directly in model*
▸ *Value calculated by model (Don't enter any data)*

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	136.0	(ft/yr)
or		or	
Hydraulic Conductivity	*K*	6.3E-03	(cm/sec)
Hydraulic Gradient	*i*	0.0073	(ft/ft)
Porosity	*n*	0.35	(-)

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	20.4	(ft)
Transverse Dispersivity*	*alpha y*	2.0	(ft)
Vertical Dispersivity*	*alpha z*	0.0	(ft)
or		or	
Estimated Plume Length	*Lp*	660	(ft)

3. ADSORPTION

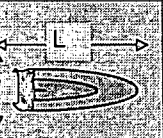
Retardation Factor*	*R*	2.1	(-)
or		or	
Soil Bulk Density	*rho*	1.7	(kg/l)
Partition Coefficient	*Koc*	38	(L/kg)
FractionOrganicCarbon	*foc*	5.7E-5	(-)

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	7.5E-1	(per yr)
or		or	
Solute Half-Life	*t-half*	1.00	(year)
or Instantaneous Reaction Model			
Delta Oxygen*	*DO*	1.41	(mg/L)
Delta Nitrate*	*NO3*	8.67	(mg/L)
Observed Ferrous Iron*	*Fe2+*	0.45	(mg/L)
Delta Sulfate*	*SO4*	23.98	(mg/L)
Observed Methane*	*CH4*	5.19	(mg/L)

5. GENERAL

Modeled Area Length*	1000	(ft)
Modeled Area Width*	200	(ft)
Simulation Time*	40	(yr)



6. SOURCE DATA

Source Thickness in Sat Zone* 3 (ft)

Source Zones:

Width* (ft)	Conc. (mg/L)*
45	0.1
25	2.5
20	10
25	2.5
45	0.1

Source Halflife (see Help):

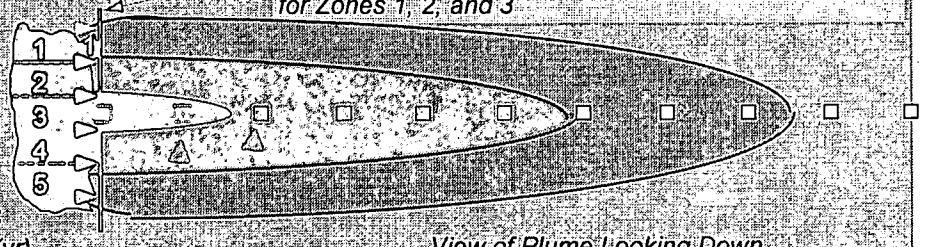
50 (yr) 400

Inst. React | 1st Order

Soluble Mass 695 (Kg)

In Source NAPL, Soil

Vertical Plane Source: Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3



View of Plume Looking Down

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
100	
200	
300	
400	
500	
600	
700	
800	
900	
1000	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

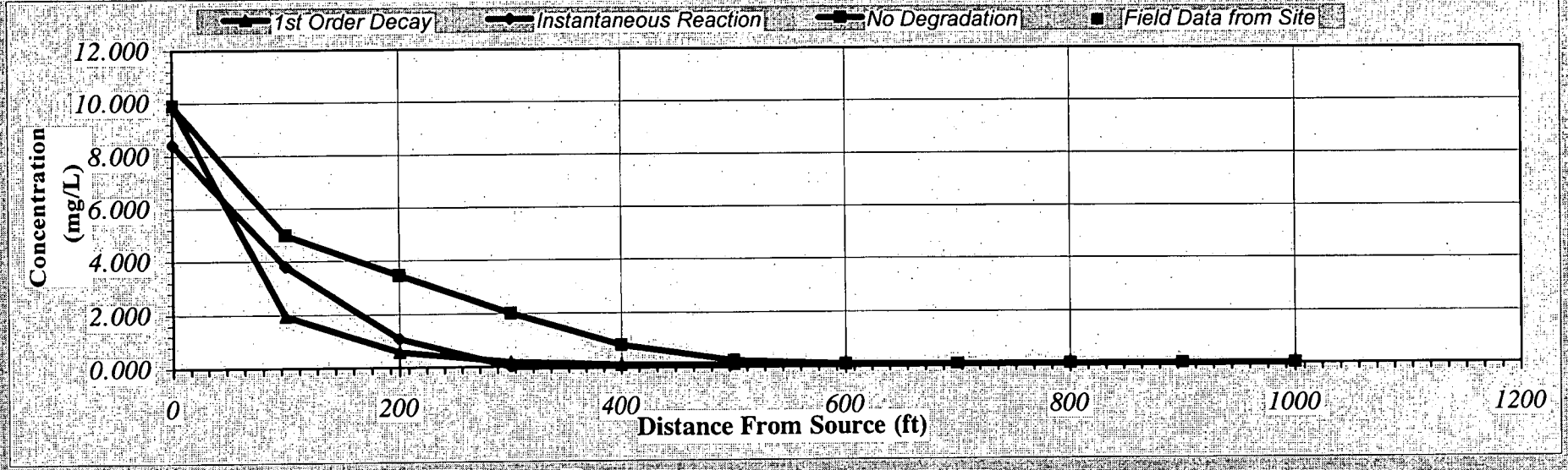
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.903	4.982	3.452	2.007	0.783	0.178	0.022	0.001	0.000	0.000	0.000
1st Order Decay	9.903	1.948	0.575	0.173	0.044	0.008	0.001	0.000	0.000	0.000	0.000
Inst. Reaction	8.421	3.813	1.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

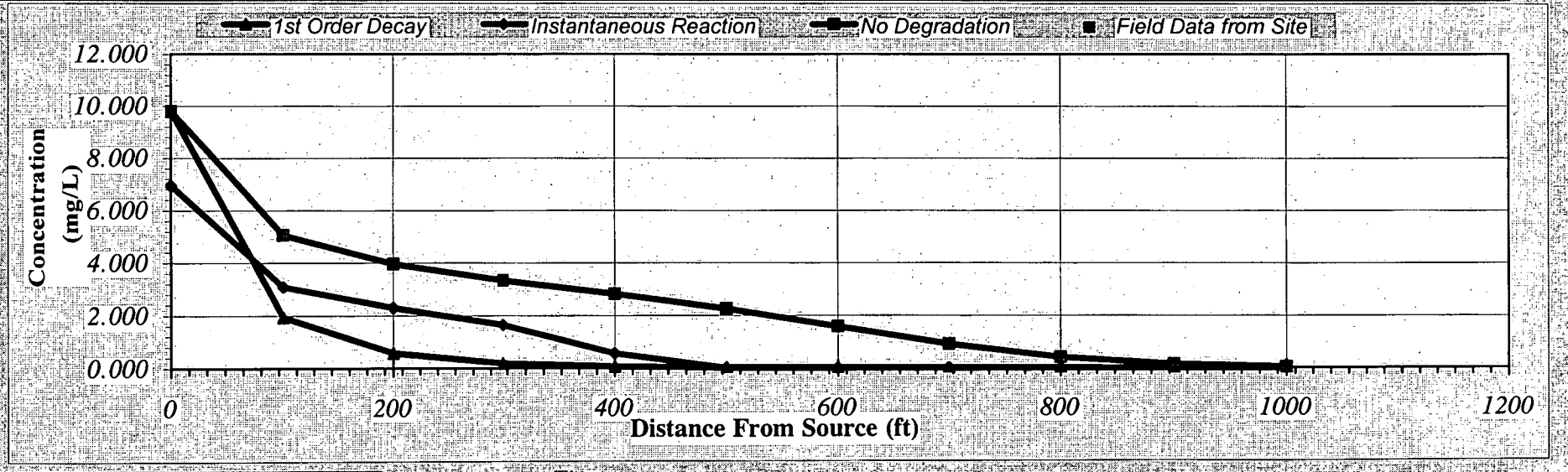
Time:
5 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z =0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.808	5.060	3.957	3.335	2.824	2.254	1.577	0.902	0.400	0.133	0.032
1st Order Decay	9.808	1.931	0.578	0.188	0.064	0.022	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	6.954	3.088	2.298	1.647	0.558	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

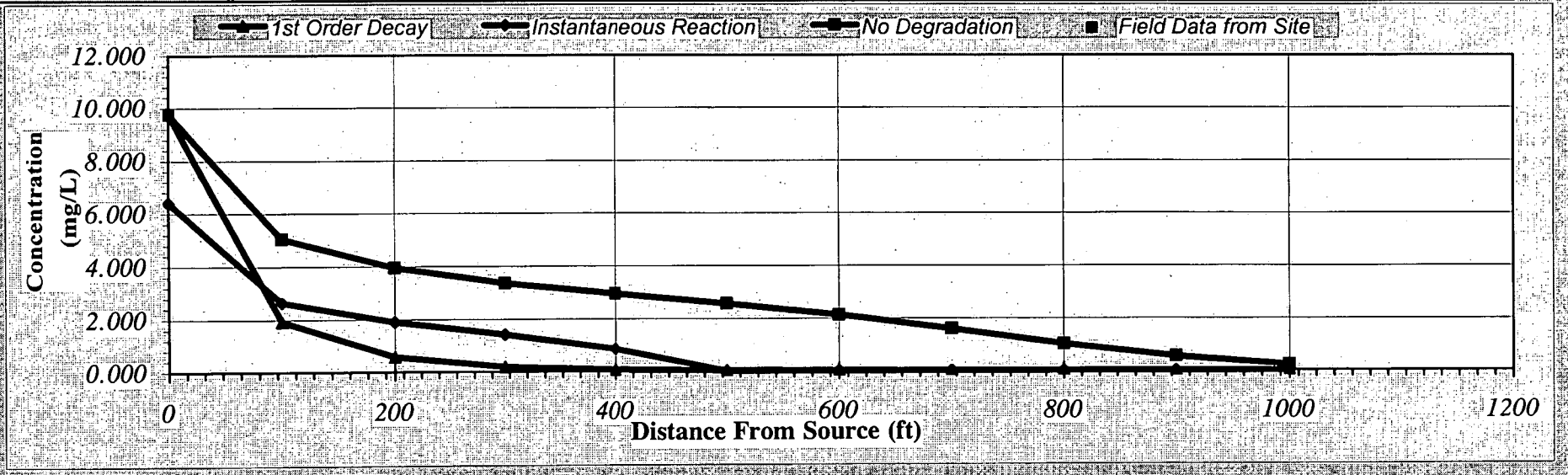
Time:
10 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.770	5.042	3.951	3.363	2.950	2.572	2.132	1.593	1.018	0.532	0.220
1st Order Decay	9.770	1.924	0.576	0.187	0.064	0.022	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	6.397	2.645	1.901	1.416	0.853	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

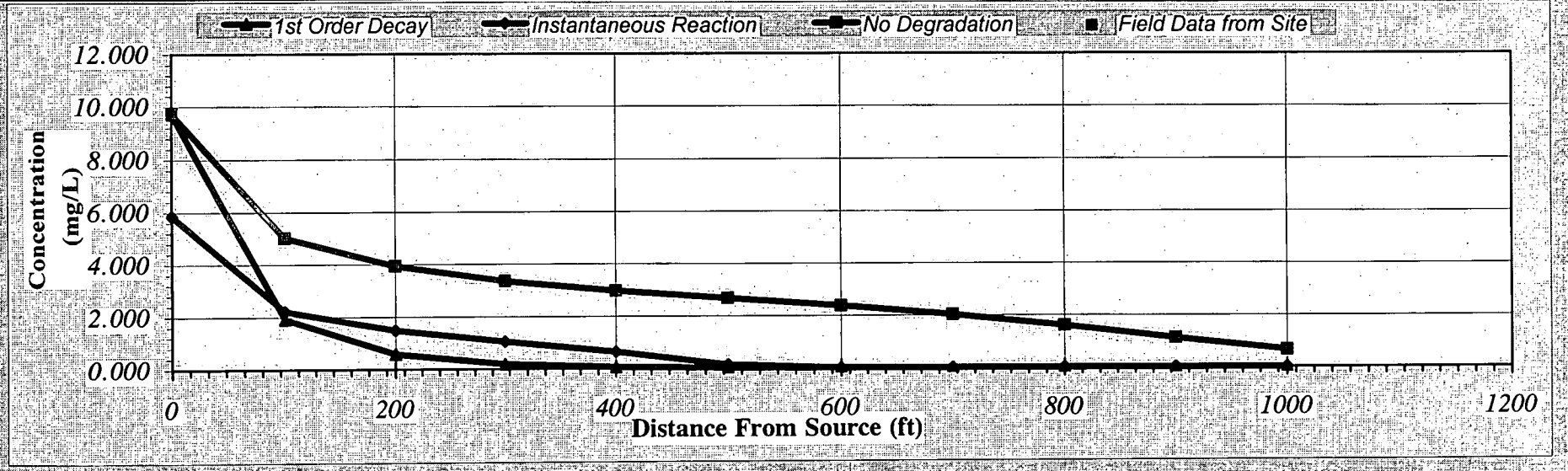
12 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.732	5.022	3.938	3.359	2.976	2.675	2.382	2.031	1.593	1.102	0.647
1st Order Decay	9.732	1.916	0.573	0.187	0.063	0.022	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	5.856	2.211	1.486	1.044	0.635	0.136	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

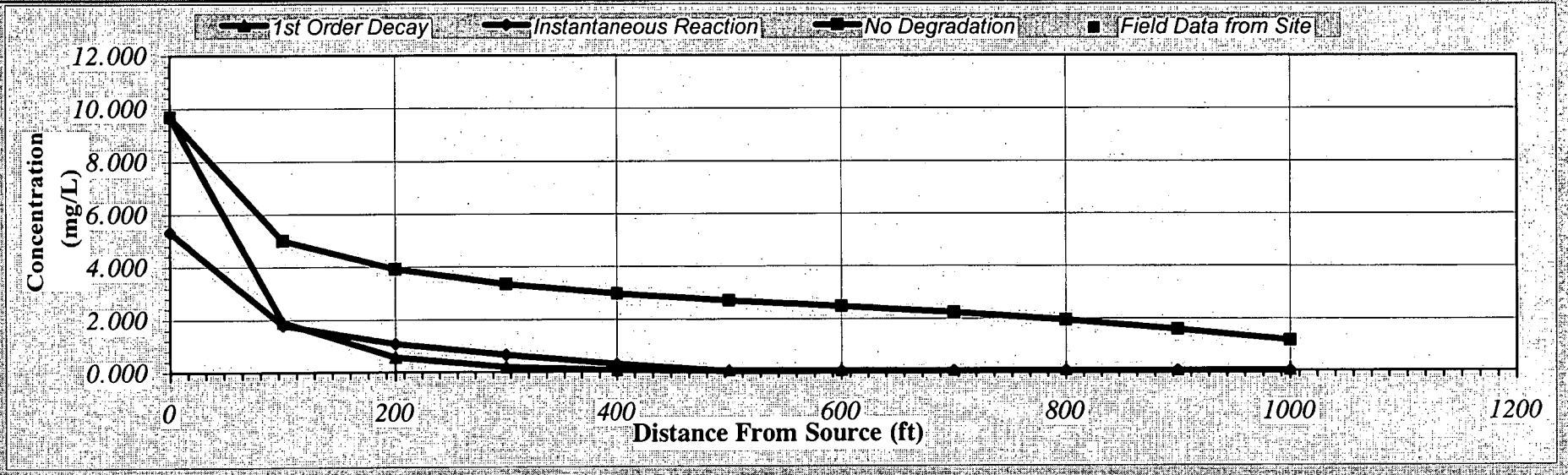
Time: 14 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.694	5.003	3.923	3.348	2.974	2.698	2.466	2.230	1.945	1.583	1.162
1st Order Decay	9.694	1.909	0.571	0.186	0.063	0.022	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	5.330	1.788	1.078	0.651	0.285	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

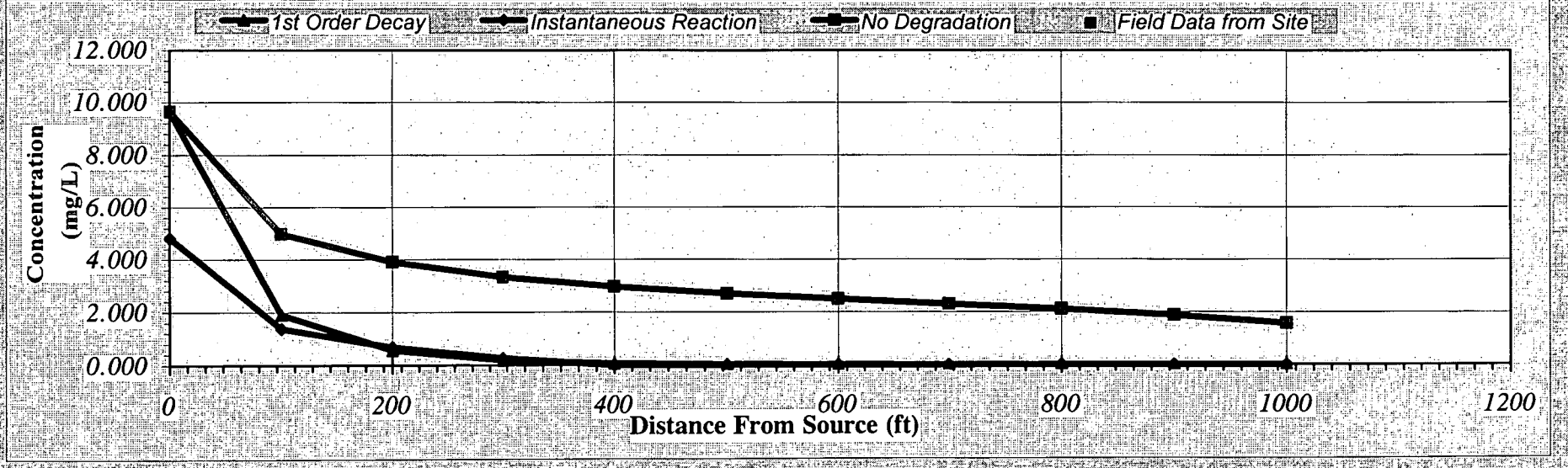
16 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.657	4.984	3.908	3.336	2.964	2.696	2.486	2.300	2.106	1.869	1.566
1st Order Decay	9.657	1.902	0.569	0.185	0.063	0.022	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	4.820	1.378	0.681	0.262	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

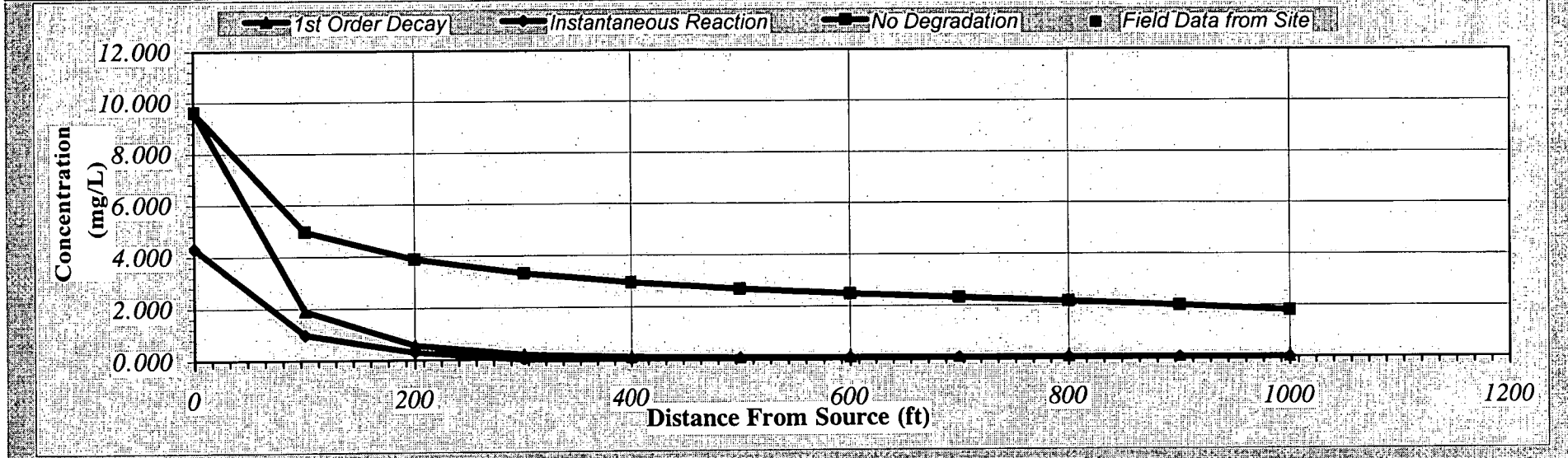
Time: 18 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft)										
	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.619	4.964	3.892	3.323	2.953	2.688	2.484	2.317	2.163	2.001	1.802
1st Order Decay	9.619	1.894	0.567	0.185	0.063	0.022	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	4.325	0.980	0.295	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

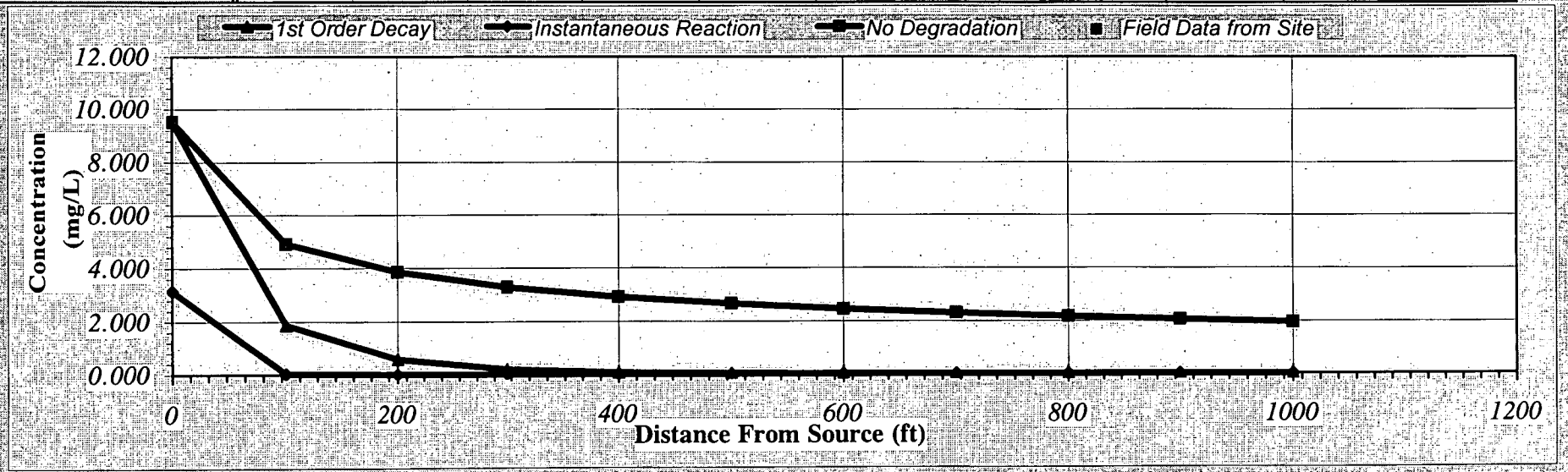
20 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.526	4.916	3.855	3.291	2.925	2.663	2.463	2.304	2.173	2.061	1.959
1st Order Decay	9.526	1.876	0.561	0.183	0.062	0.022	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	3.149	0.033	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time: 25 Years

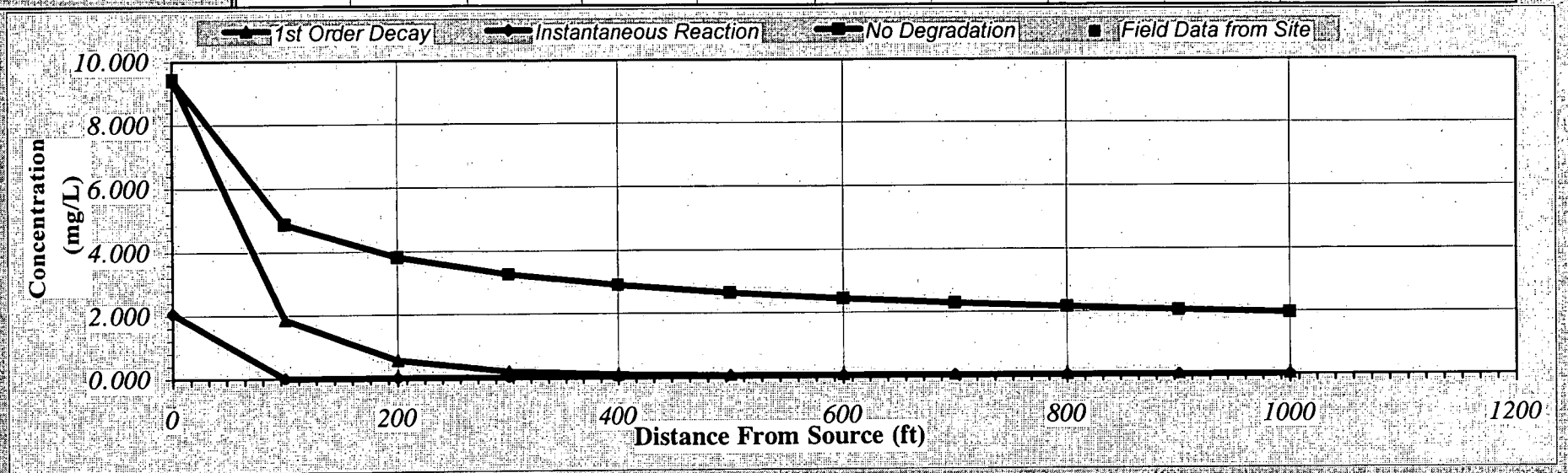
Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.434	4.869	3.818	3.259	2.897	2.637	2.439	2.282	2.154	2.046	1.954
1st Order Decay	9.434	1.858	0.556	0.181	0.061	0.021	0.008	0.003	0.001	0.000	0.000
Inst. Reaction	2.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

Time:
30 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.343	4.822	3.781	3.227	2.869	2.612	2.416	2.260	2.133	2.026	1.935
1st Order Decay	9.343	1.840	0.550	0.179	0.061	0.021	0.007	0.003	0.001	0.000	0.000
Inst. Reaction	1.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
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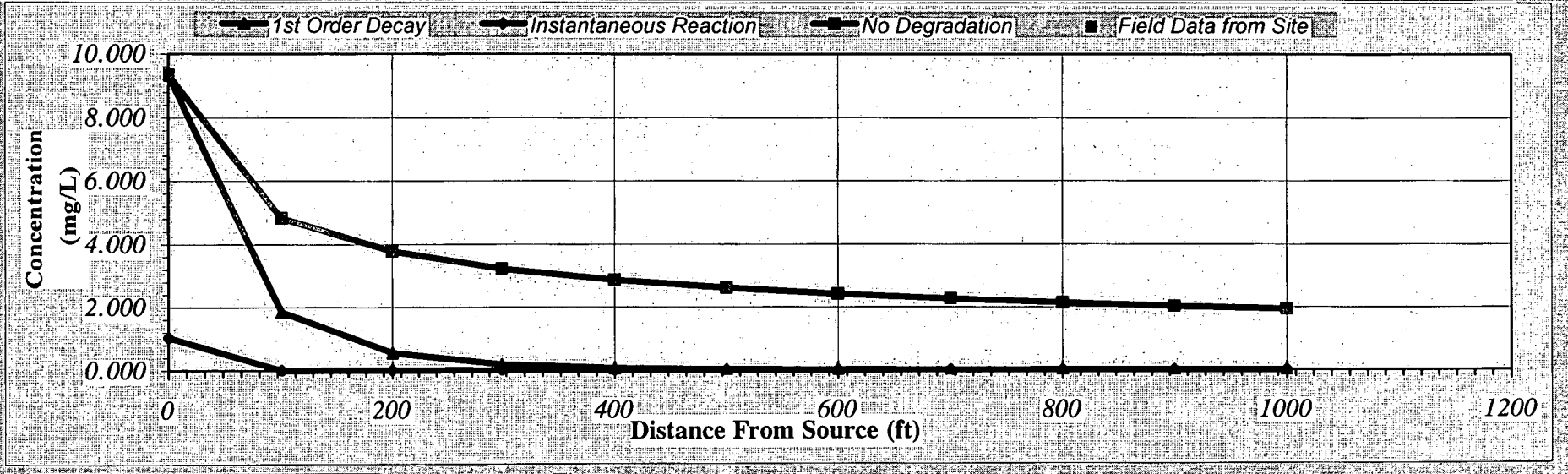


Calculate Animation
Next Timestep
Prev Timestep

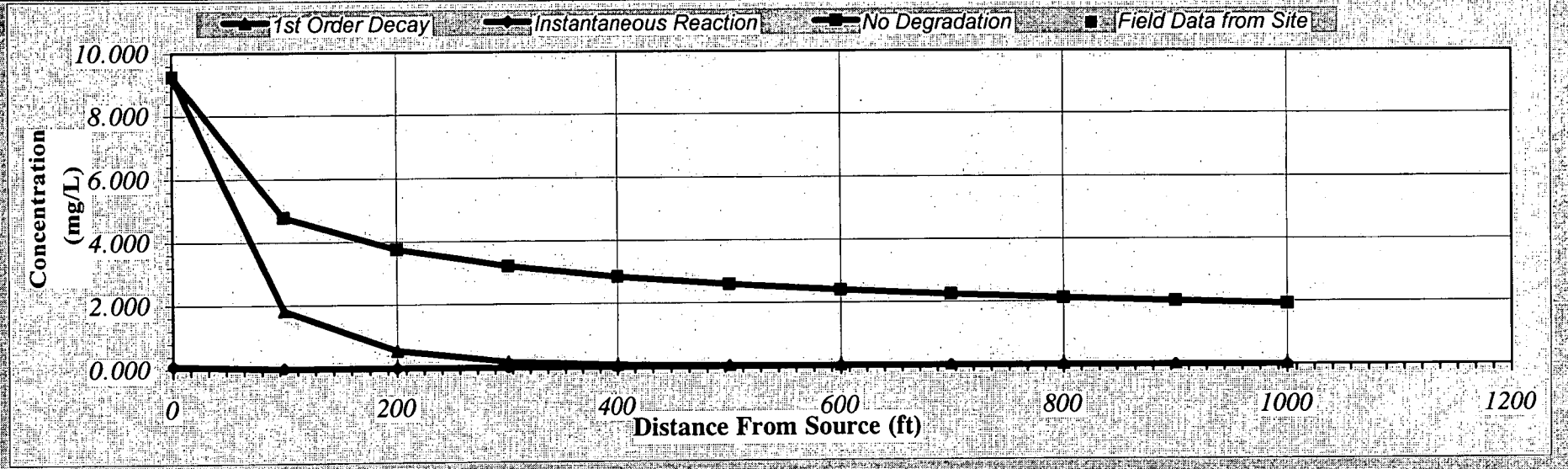
Time:
35 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.253	4.775	3.744	3.196	2.841	2.586	2.392	2.239	2.112	2.007	1.917
1st Order Decay	9.253	1.822	0.545	0.178	0.060	0.021	0.007	0.003	0.001	0.000	0.000
Inst. Reaction	0.098	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

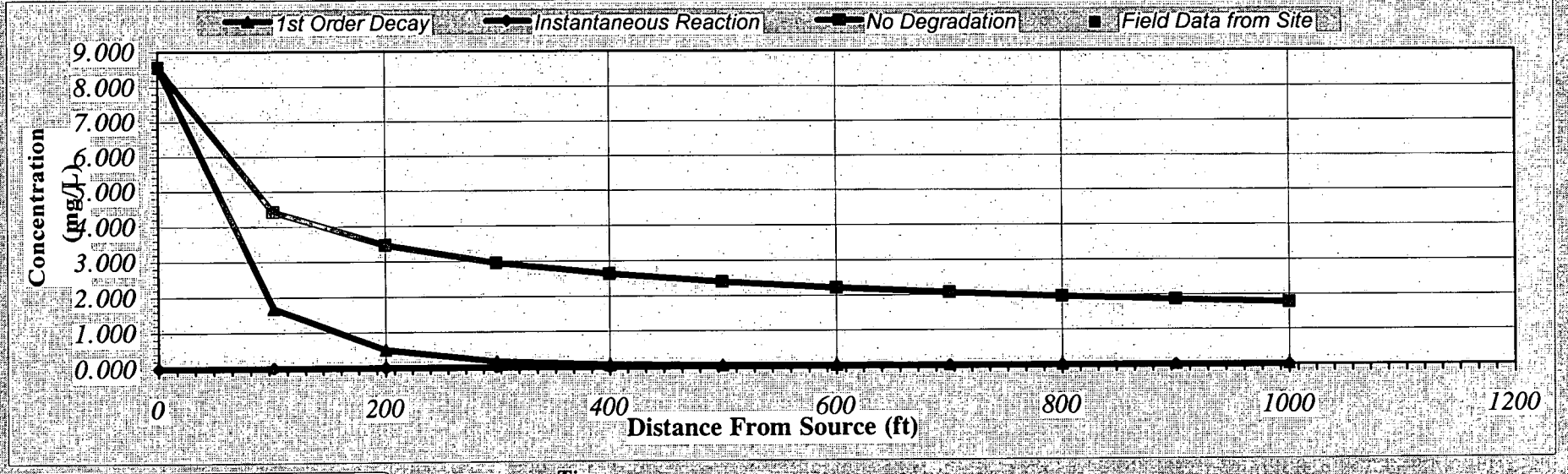
Time:
40 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	8.561	4.419	3.464	2.957	2.629	2.393	2.214	2.071	1.955	1.857	1.774
1st Order Decay	8.561	1.686	0.504	0.164	0.056	0.019	0.007	0.002	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

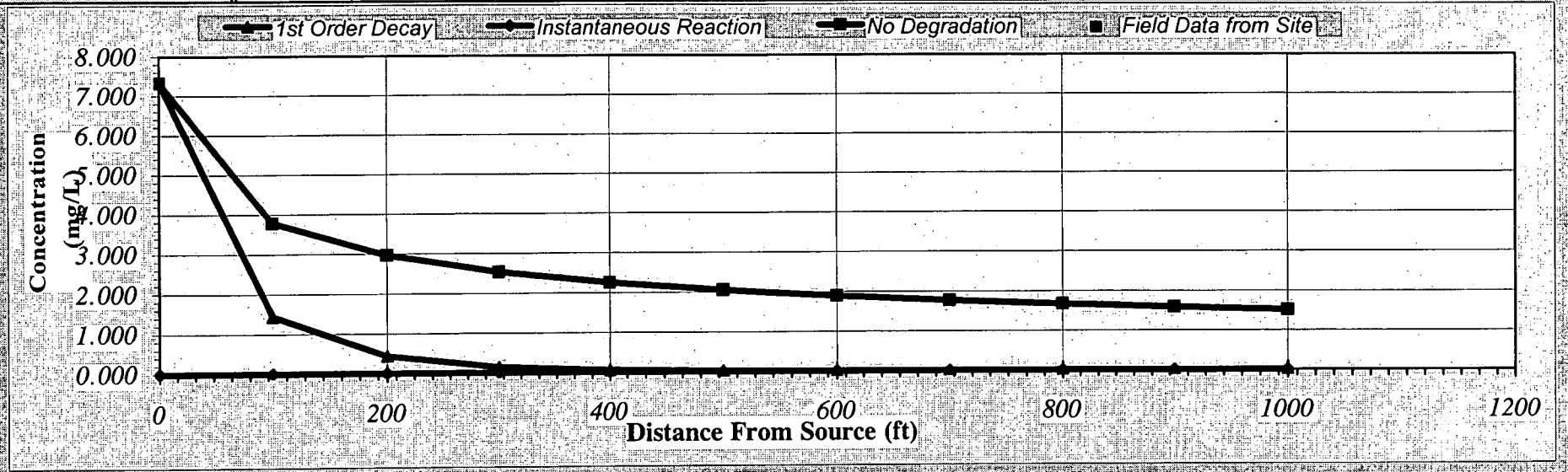
80 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	7.330	3.783	2.966	2.532	2.250	2.049	1.895	1.773	1.673	1.590	1.518
1st Order Decay	7.330	1.443	0.432	0.141	0.048	0.017	0.006	0.002	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

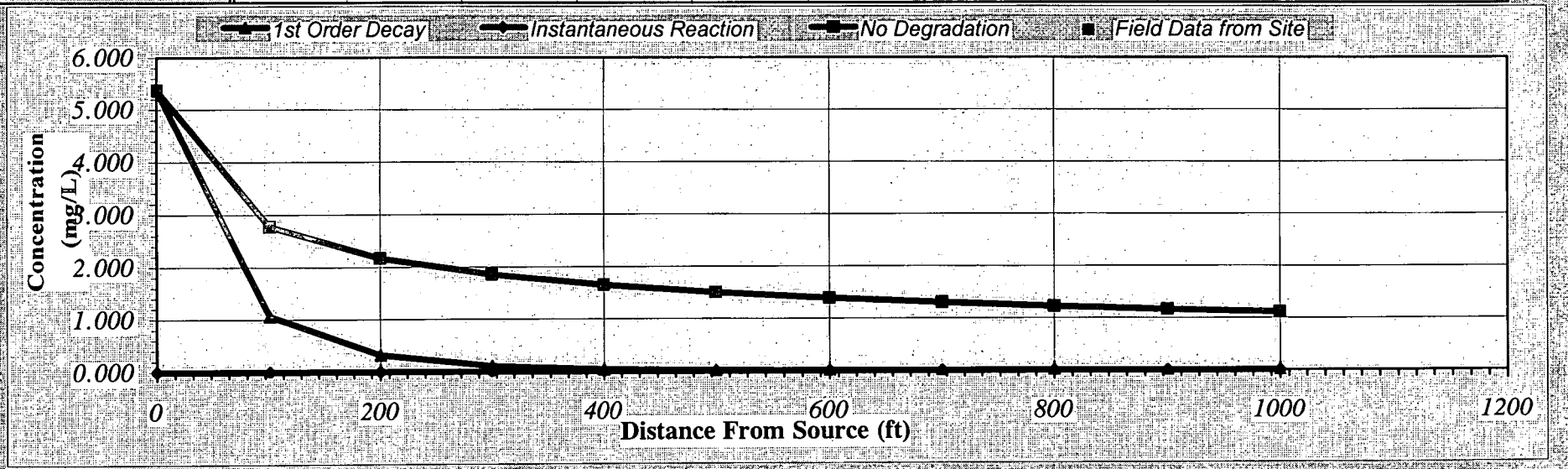
Time:
160 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	5.373	2.773	2.174	1.856	1.650	1.502	1.389	1.300	1.227	1.165	1.113
1st Order Decay	5.373	1.058	0.317	0.103	0.035	0.012	0.004	0.002	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

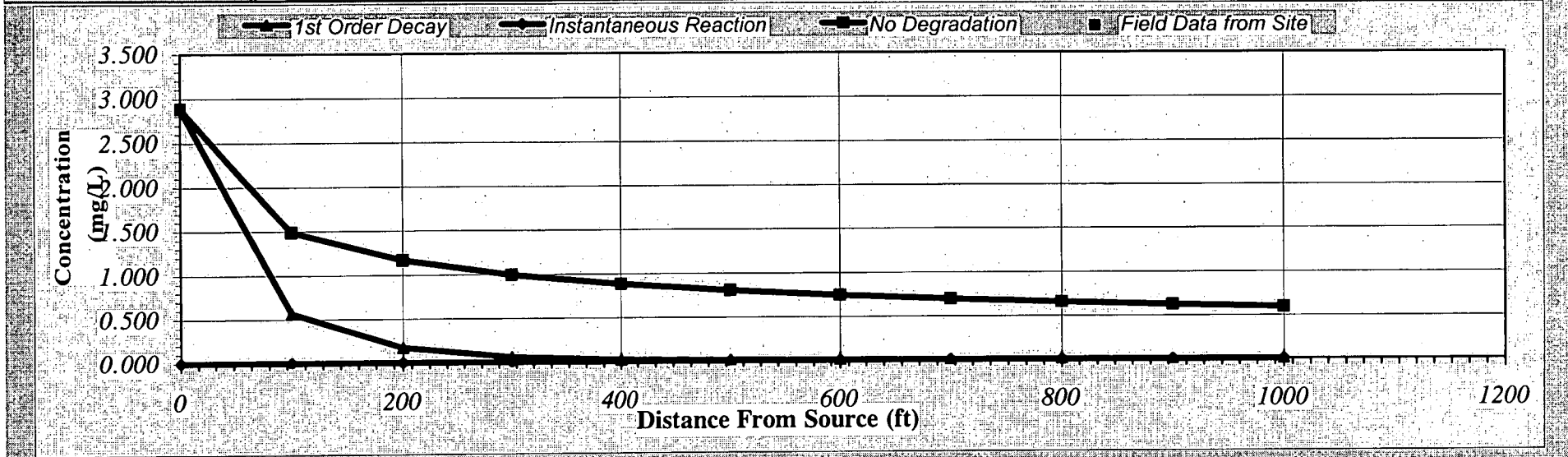
Time: 320 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	2.887	1.490	1.168	0.997	0.886	0.807	0.746	0.698	0.659	0.626	0.598
1st Order Decay	2.887	0.568	0.170	0.055	0.019	0.007	0.002	0.001	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

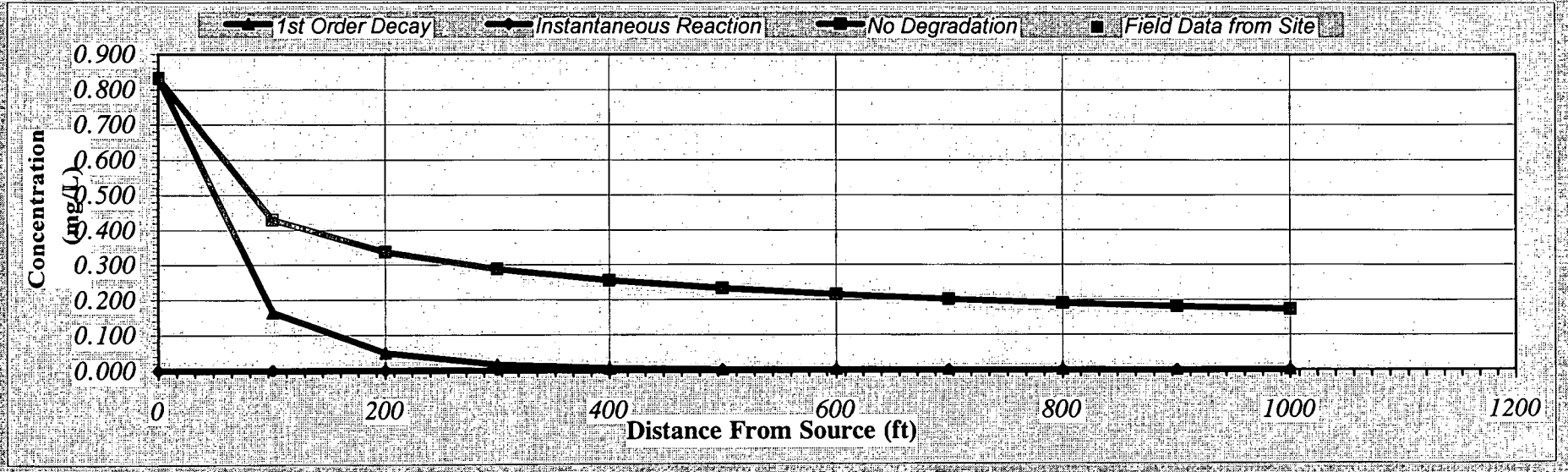
640 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.833	0.430	0.337	0.288	0.256	0.233	0.215	0.202	0.190	0.181	0.173
1st Order Decay	0.833	0.164	0.049	0.016	0.005	0.002	0.001	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

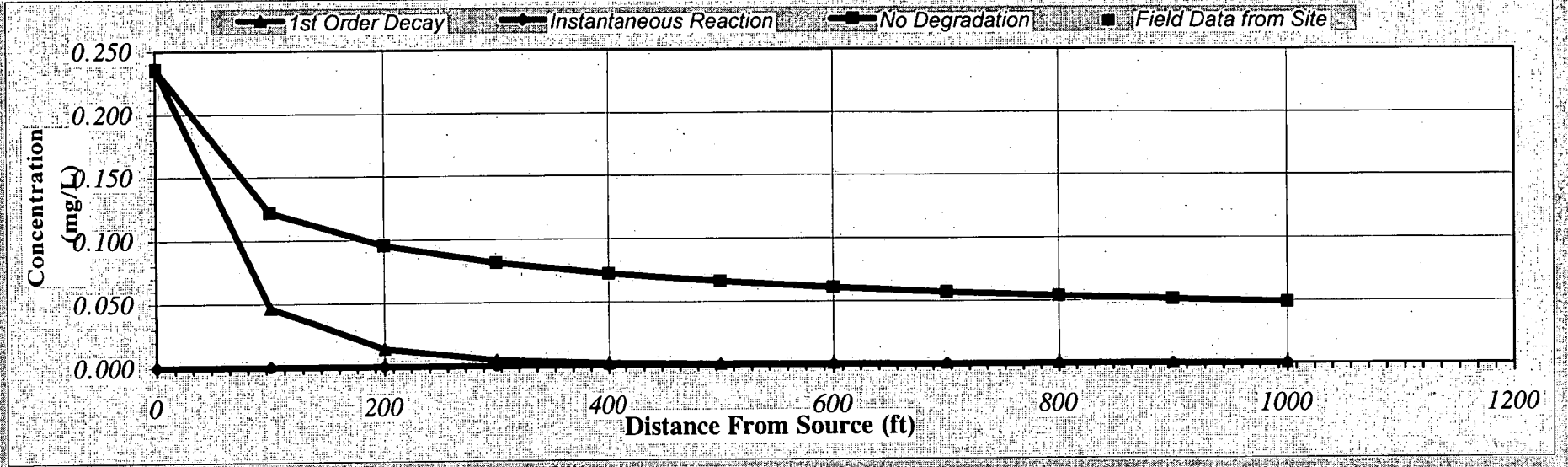
Time:
1,280 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.236	0.122	0.095	0.081	0.072	0.066	0.061	0.057	0.054	0.051	0.049
1st Order Decay	0.236	0.046	0.014	0.005	0.002	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Next Timestep
Animation Prev Timestep

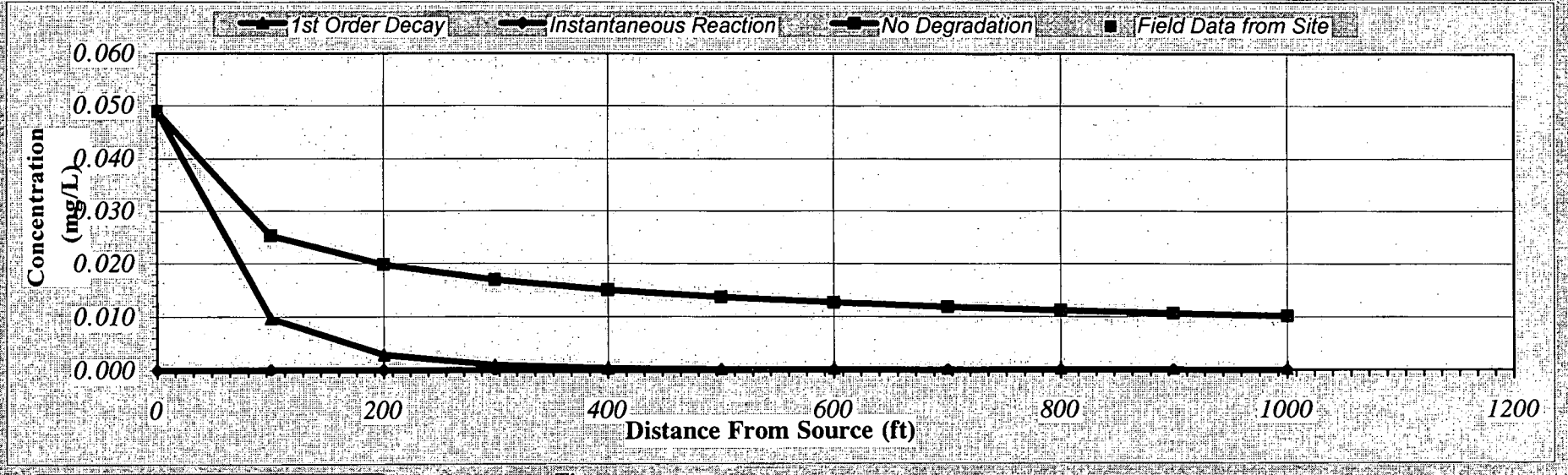
Time:
1,930 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.049	0.025	0.020	0.017	0.015	0.014	0.013	0.012	0.011	0.011	0.010
1st Order Decay	0.049	0.010	0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

Time:
2,740 Years

Return to Input

Recalculate This Sheet

BIOSCREEN Natural Attenuation Decision Support System

Air Force Center for Environmental Excellence — *Version 1.4*

NAS Brunswick
DRO-West Prediction
Run Name

Data Input Instructions:
1. Enter value directly... or
2. Calculate by filling in grey cells below. (To restore formulas, hit button below)

Variable* ▸ Data used directly in model
20 ▸ Value calculated by model (Don't enter any data)

1. HYDROGEOLOGY

Seepage Velocity*	*Vs*	136.0	*(ft/yr)*
or		↑ or	
Hydraulic Conductivity	*K*	6.3E-03	*(cm/sec)*
Hydraulic Gradient	*I*	0.0073	*(ft/ft)*
Porosity	*n*	0.35	*(-)*

2. DISPERSION

Longitudinal Dispersivity*	*alpha x*	19.5	*(ft)*
Transverse Dispersivity*	*alpha y*	2.0	*(ft)*
Vertical Dispersivity*	*alpha z*	0.0	*(ft)*
or		↑ or	
Estimated Plume Length	*Lp*	600	*(ft)*

3. ADSORPTION

Retardation Factor*	*R*	2.1	*(-)*
or		↑ or	
Soil Bulk Density	*rho*	1.7	*(kg/l)*
Partition Coefficient	*Koc*	38	*(L/kg)*
FractionOrganicCarbon	*foc*	5.7E-5	*(-)*

4. BIODEGRADATION

1st Order Decay Coeff*	*lambda*	7.5E-1	*(per yr)*
or		↑ or	
Solute Half-Life	*t-half*	1.00	*(year)*

or Instantaneous Reaction Model

Delta Oxygen*	*DO*	1.41	*(mg/L)*
Delta Nitrate*	*NO3*	8.67	*(mg/L)*
Observed Ferrous Iron*	*Fe2+*	0.45	*(mg/L)*
Delta Sulfate*	*SO4*	23.98	*(mg/L)*
Observed Methane*	*CH4*	5.19	*(mg/L)*

5. GENERAL

Modeled Area Length*	1000	*(ft)*
Modeled Area Width*	200	*(ft)*
Simulation Time*	30	*(yr)*

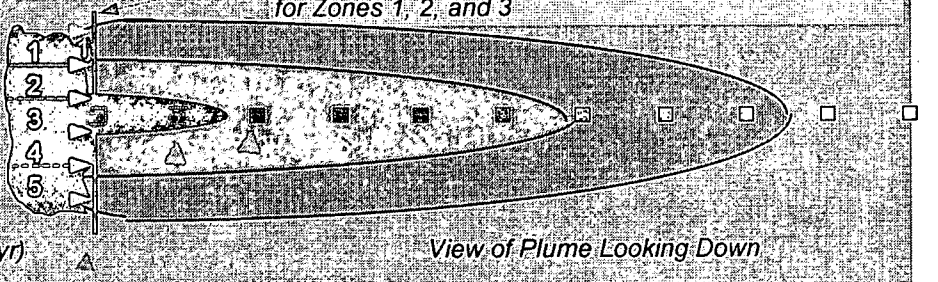
6. SOURCE DATA

Source Thickness in Sat Zone* 3 *(ft)*

Vertical Plane Source. Look at Plume Cross-Section and Input Concentrations & Widths for Zones 1, 2, and 3

Source Zones

Width* (ft)	Conc. (mg/L)*
100	0.1
25	5
20	10
25	5
100	0.1



View of Plume Looking Down

Source Halflife (see Help): 30 300 *(yr)*

Inst. React ↑ ↑ 1st Order

Soluble Mass 689 *(Kg)*

In Source NAPL Soil

Observed Centerline Concentrations at Monitoring Wells
If No Data Leave Blank or Enter "0"

7. FIELD DATA FOR COMPARISON

Dist. from Source (ft)	Concentration (mg/L)
0	
100	
200	
300	
400	
500	
600	
700	
800	
900	
1000	

8. CHOOSE TYPE OF OUTPUT TO SEE:

RUN CENTERLINE — View Output

RUN ARRAY — View Output

Help

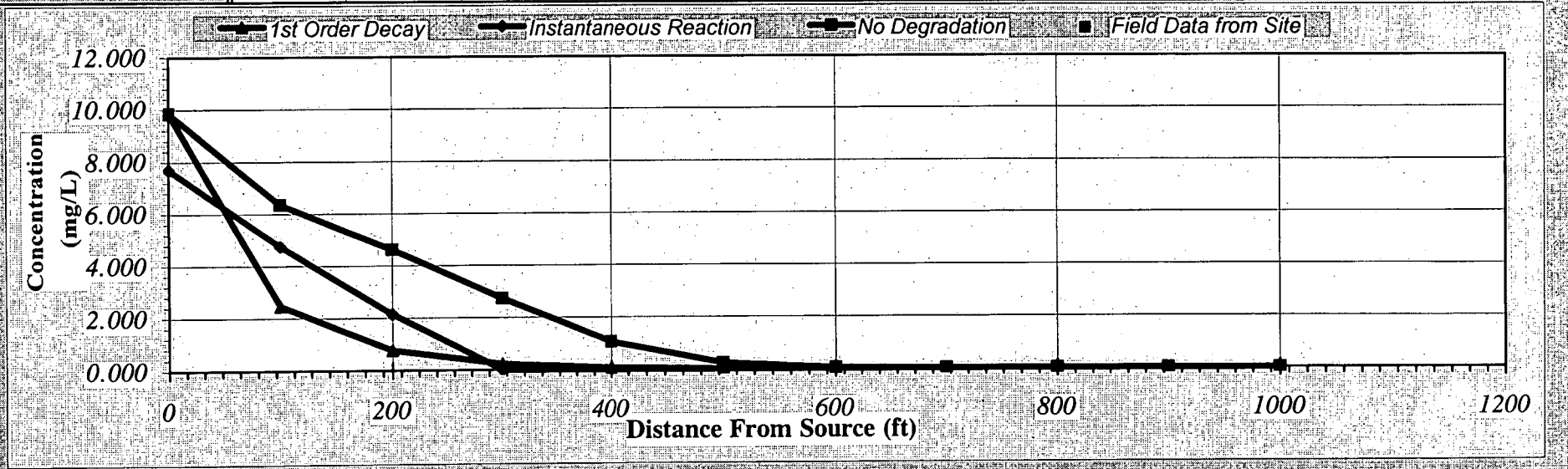
Recalculate This Sheet

Paste Example Dataset

Restore Formulas for Vs, Dispersivities, R, lambda, other

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.863	6.349	4.626	2.732	1.054	0.230	0.026	0.001	0.000	0.000	0.000
1st Order Decay	9.863	2.462	0.757	0.230	0.057	0.010	0.001	0.000	0.000	0.000	0.000
Inst. Reaction	7.697	4.754	2.139	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

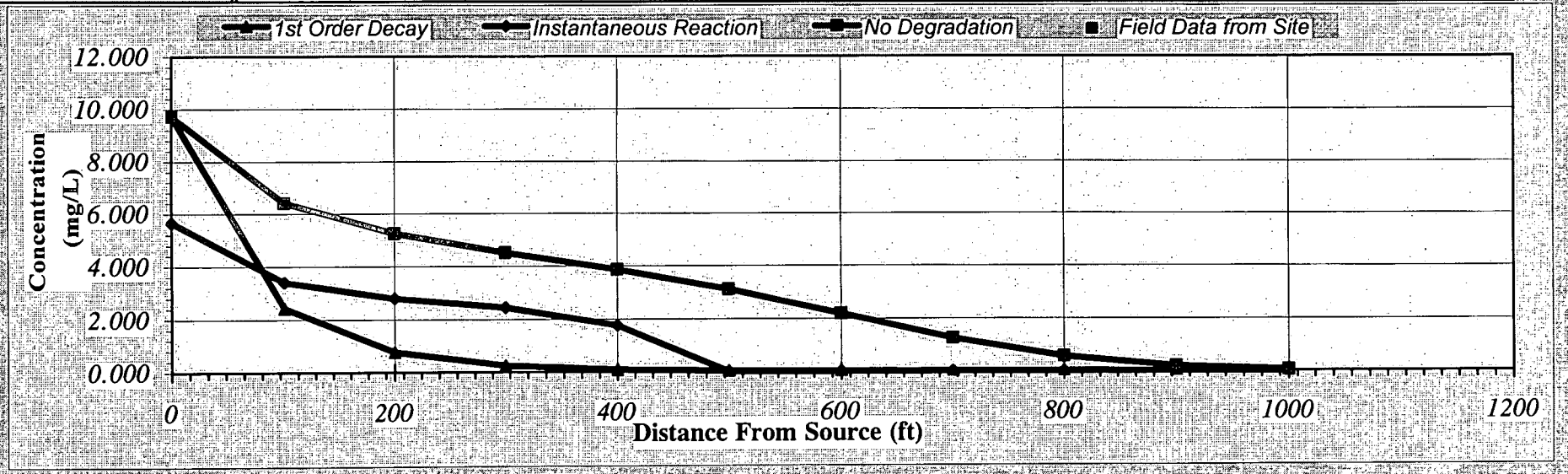
5 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.728	6.407	5.252	4.514	3.874	3.120	2.190	1.244	0.541	0.173	0.040
1st Order Decay	9.728	2.431	0.757	0.250	0.085	0.029	0.010	0.003	0.001	0.000	0.000
Inst. Reaction	5.656	3.404	2.798	2.448	1.764	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

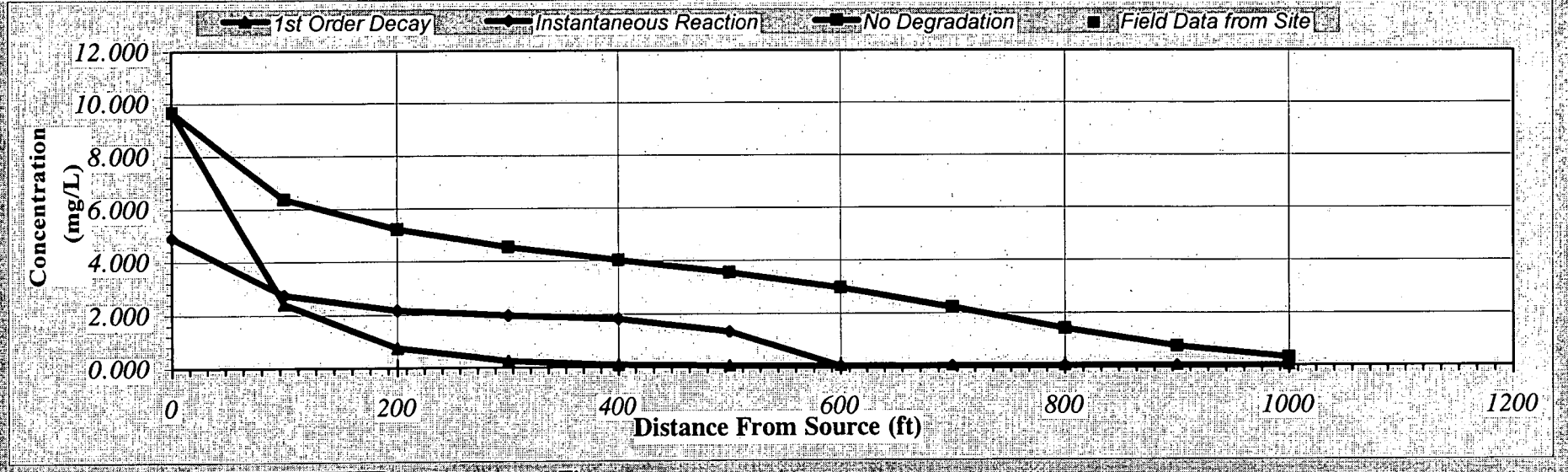
Time: 10 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.675	6.373	5.233	4.539	4.030	3.548	2.964	2.223	1.415	0.728	0.294
1st Order Decay	9.675	2.418	0.753	0.248	0.085	0.029	0.010	0.004	0.001	0.000	0.000
Inst. Reaction	4.907	2.753	2.176	1.967	1.817	1.331	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

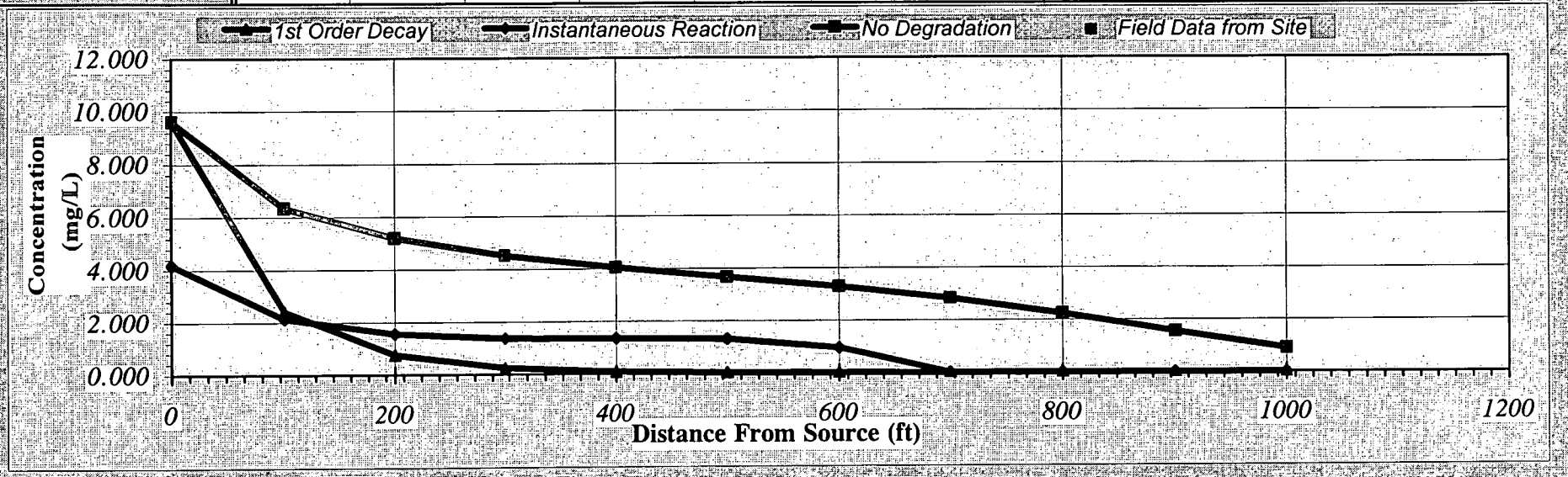
Time: 12 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.622	6.338	5.206	4.525	4.053	3.675	3.297	2.831	2.229	1.540	0.894
1st Order Decay	9.622	2.404	0.749	0.247	0.084	0.029	0.010	0.004	0.001	0.000	0.000
Inst. Reaction	4.192	2.129	1.558	1.371	1.350	1.310	0.960	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

Time:
14 Years

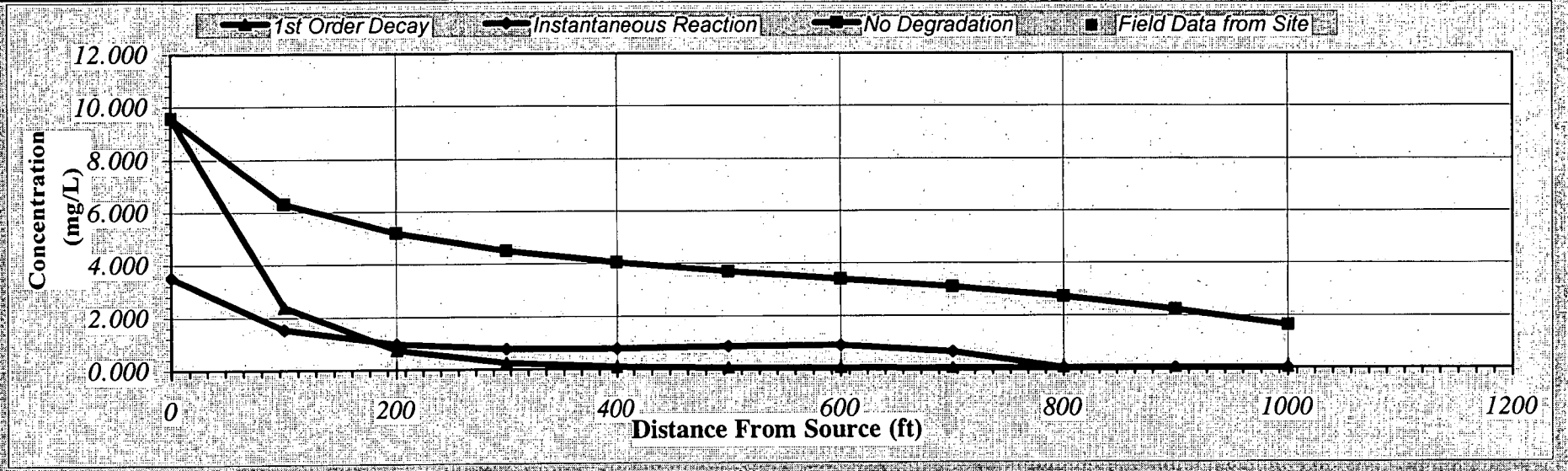
Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

Distance from Source (ft)

TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.569	6.304	5.178	4.502	4.042	3.696	3.401	3.096	2.716	2.219	1.629
1st Order Decay	9.569	2.391	0.745	0.246	0.084	0.029	0.010	0.004	0.001	0.000	0.000
Inst. Reaction	3.512	1.534	0.965	0.774	0.772	0.848	0.871	0.621	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

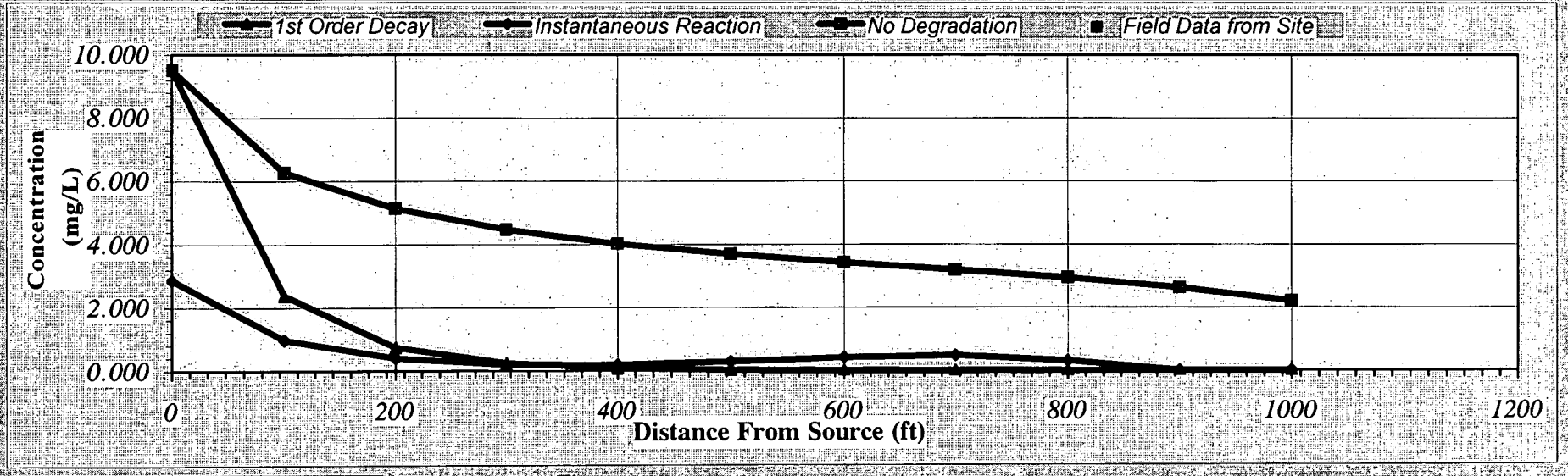
16 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.516	6.269	5.149	4.478	4.022	3.686	3.419	3.181	2.930	2.615	2.200
1st Order Decay	9.516	2.378	0.741	0.244	0.083	0.029	0.010	0.004	0.001	0.000	0.000
Inst. Reaction	2.863	0.966	0.399	0.199	0.191	0.284	0.411	0.474	0.300	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

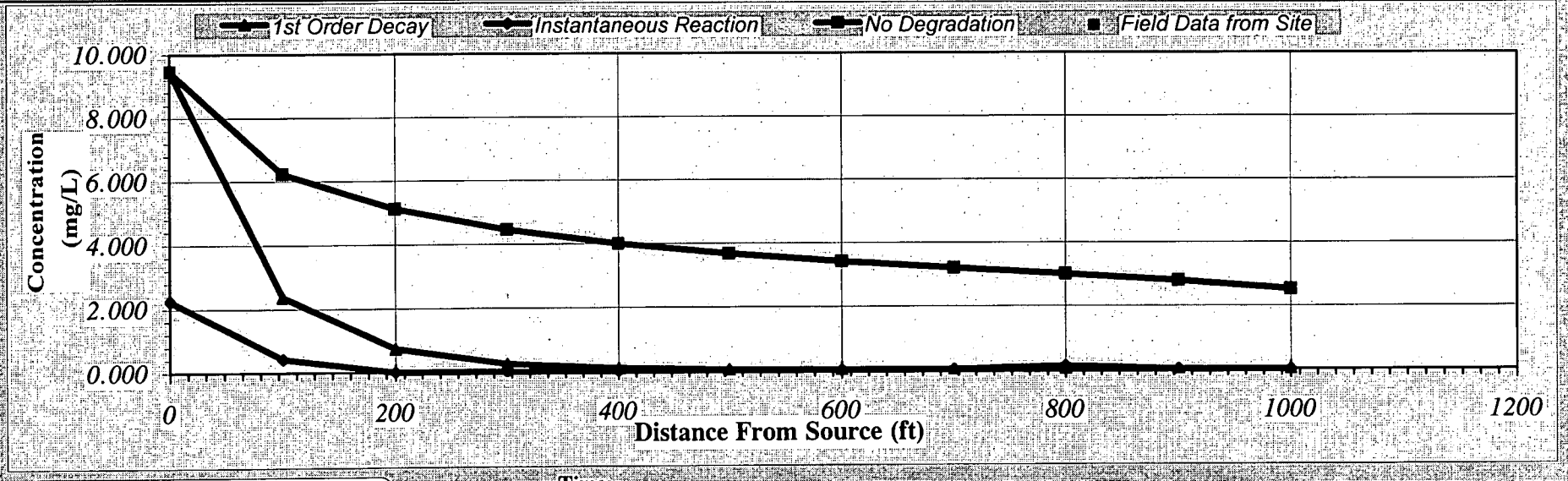
Time:
18 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

	Distance from Source (ft)										
TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.464	6.235	5.121	4.453	4.000	3.668	3.410	3.196	3.000	2.789	2.524
1st Order Decay	9.464	2.365	0.737	0.243	0.083	0.029	0.010	0.004	0.001	0.000	0.000
Inst. Reaction	2.244	0.426	0.000	0.000	0.000	0.000	0.000	0.013	0.103	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

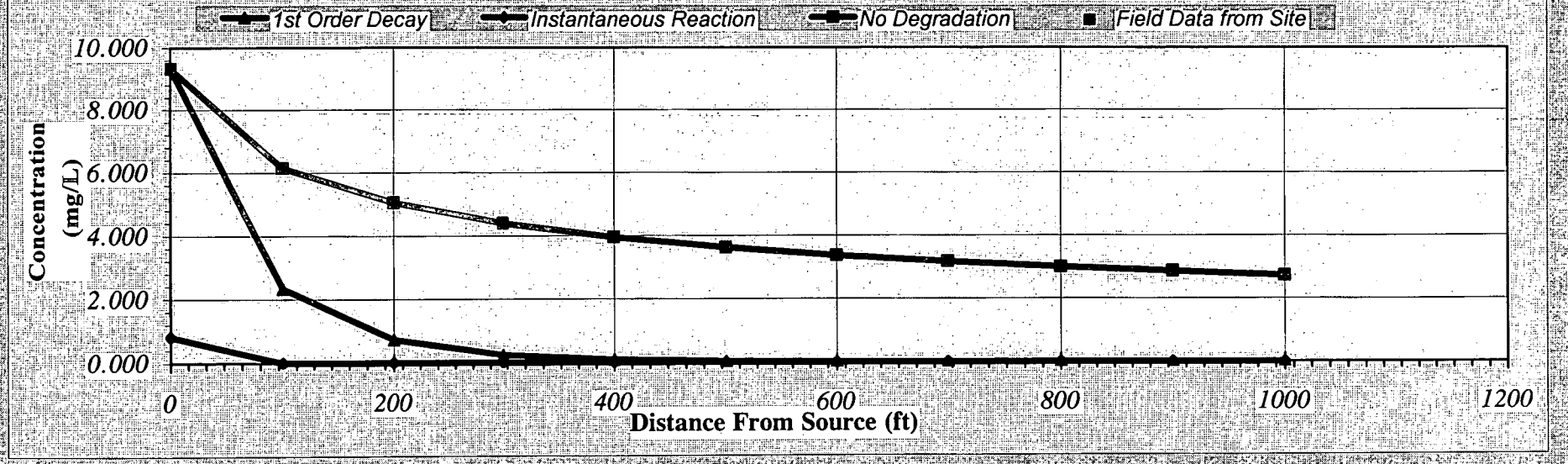
20 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z = 0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.334	6.149	5.051	4.393	3.946	3.619	3.366	3.164	2.996	2.853	2.721
1st Order Decay	9.334	2.332	0.727	0.240	0.082	0.028	0.010	0.004	0.001	0.000	0.000
Inst. Reaction	0.822	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

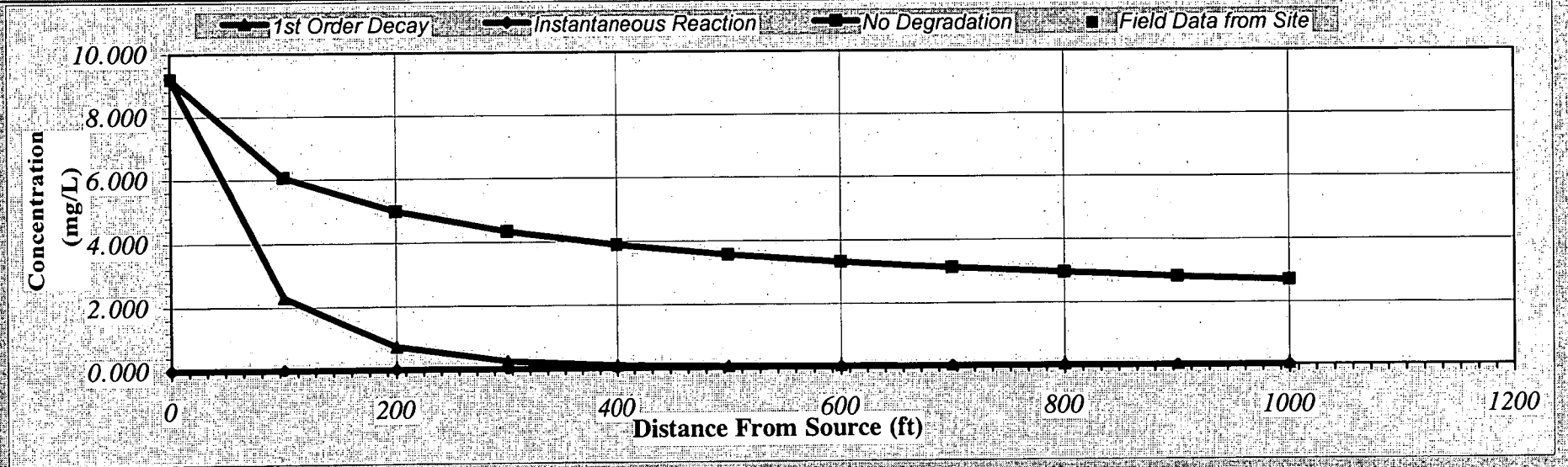
Time:
25 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	9.207	6.065	4.982	4.332	3.892	3.569	3.320	3.121	2.957	2.819	2.701
1st Order Decay	9.207	2.301	0.717	0.236	0.081	0.028	0.010	0.004	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

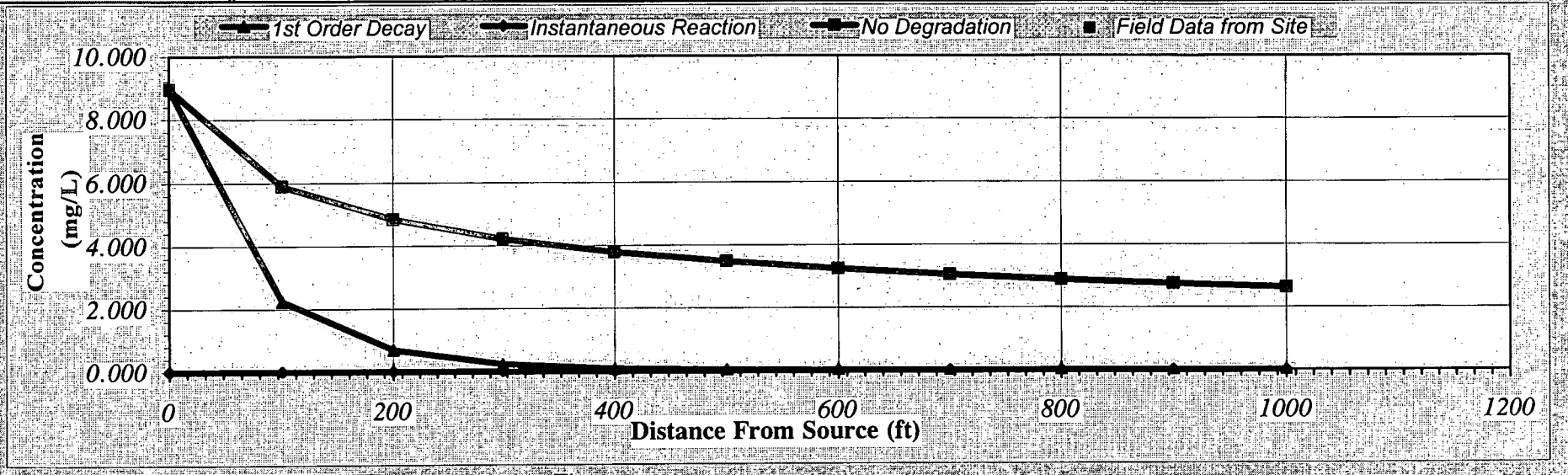
Time: 30 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	8.956	5.900	4.846	4.215	3.786	3.472	3.230	3.036	2.877	2.743	2.628
1st Order Decay	8.956	2.238	0.697	0.230	0.078	0.027	0.010	0.003	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time: 40 Years

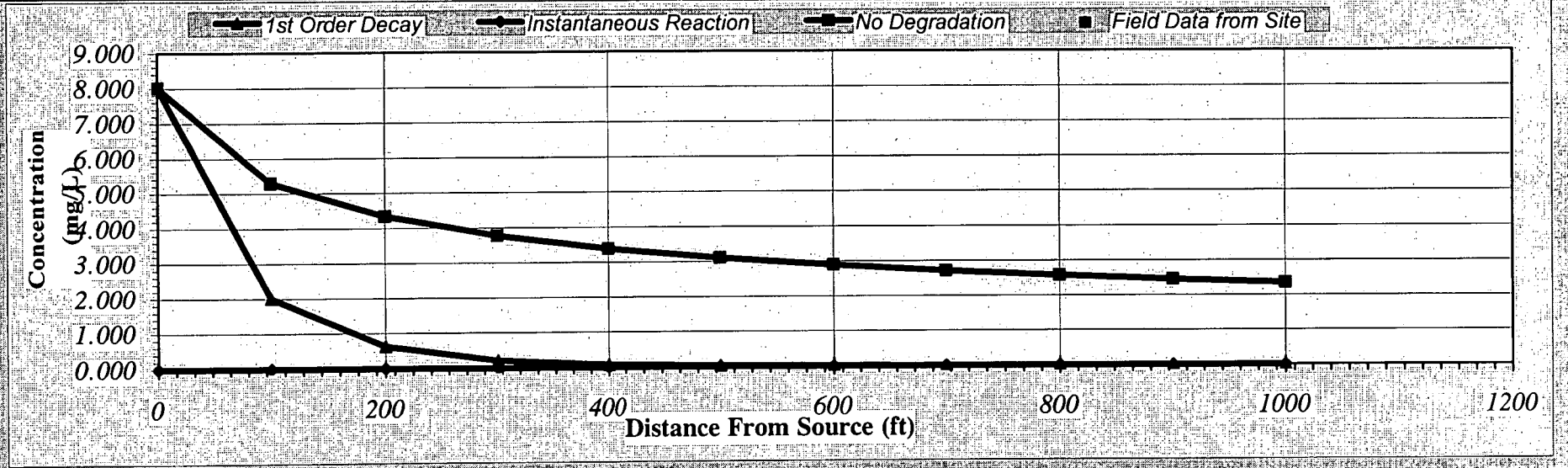
Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	8.021	5.284	4.341	3.775	3.391	3.110	2.893	2.719	2.576	2.456	2.354
1st Order Decay	8.021	2.004	0.625	0.206	0.070	0.024	0.009	0.003	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

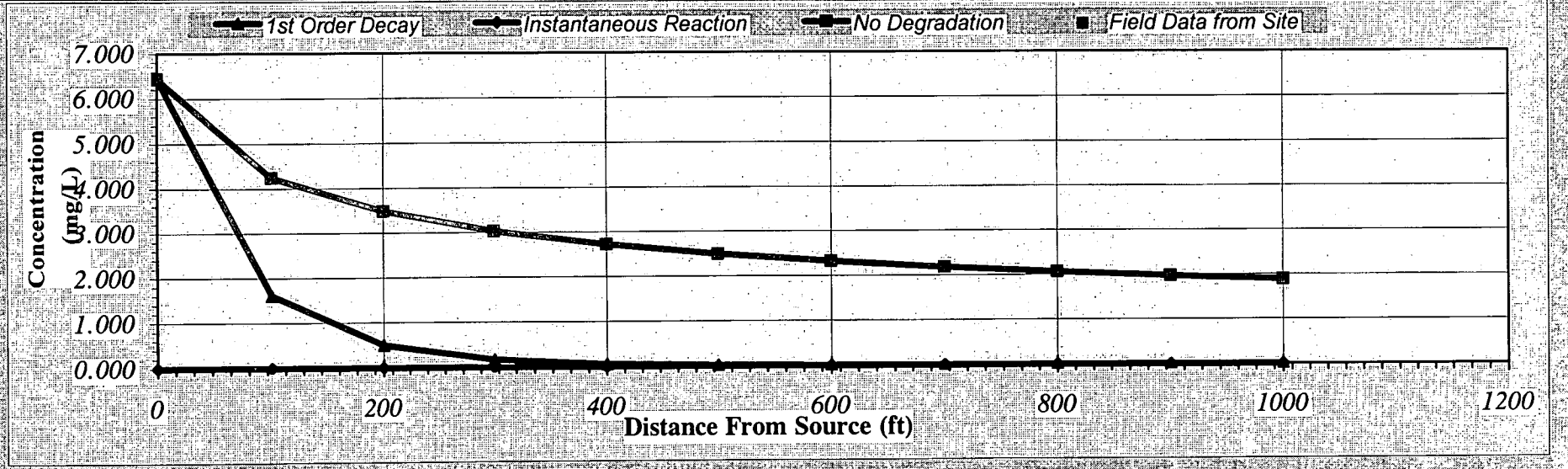
80 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	6.434	4.239	3.482	3.028	2.720	2.494	2.320	2.181	2.067	1.970	1.888
1st Order Decay	6.434	1.608	0.501	0.165	0.056	0.020	0.007	0.002	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation
Next Timestep
Prev Timestep

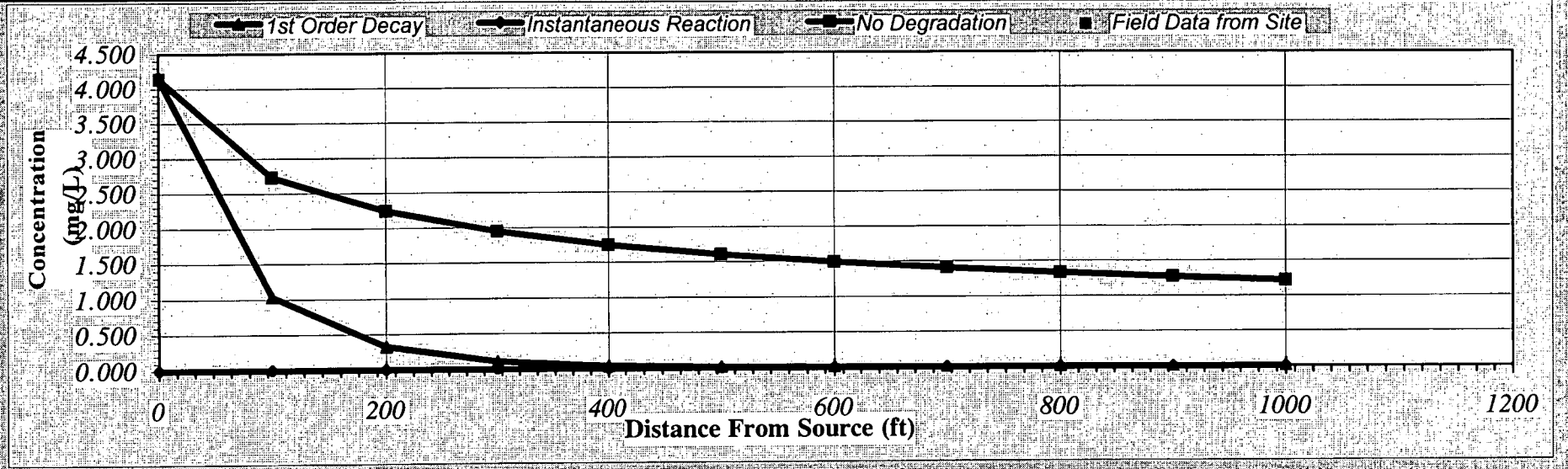
Time:
160 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	4.140	2.727	2.240	1.948	1.750	1.605	1.493	1.404	1.330	1.268	1.215
1st Order Decay	4.140	1.035	0.322	0.106	0.036	0.013	0.004	0.002	0.001	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

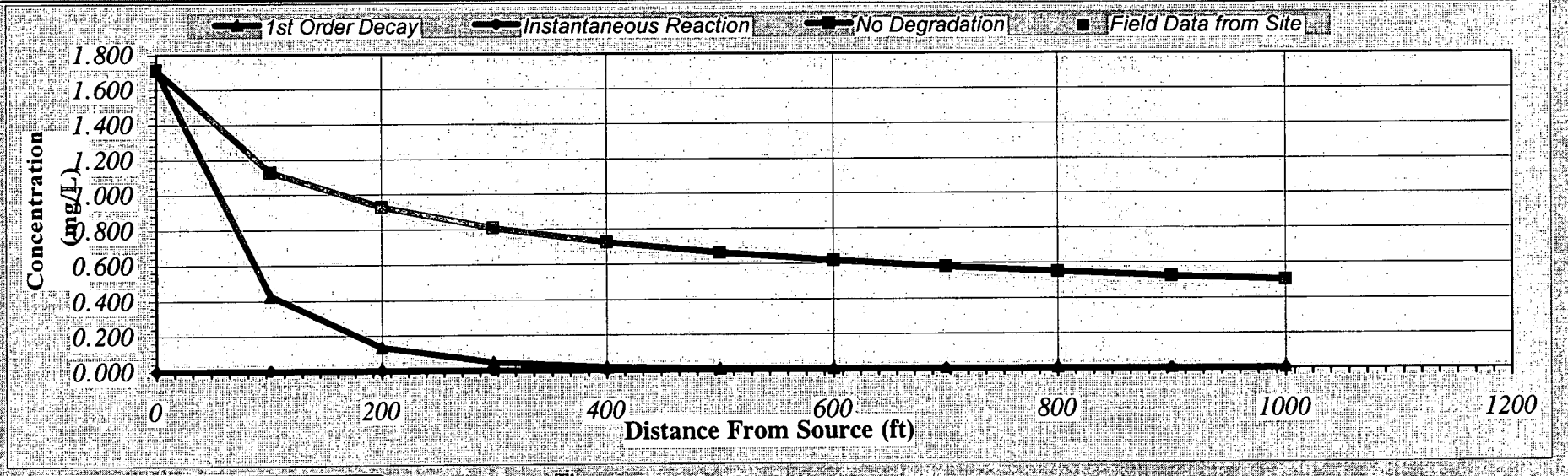
320 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	1.714	1.129	0.928	0.807	0.725	0.665	0.618	0.581	0.551	0.525	0.503
1st Order Decay	1.714	0.428	0.133	0.044	0.015	0.005	0.002	0.001	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation: Next Timestep / Prev Timestep

Time: 640 Years

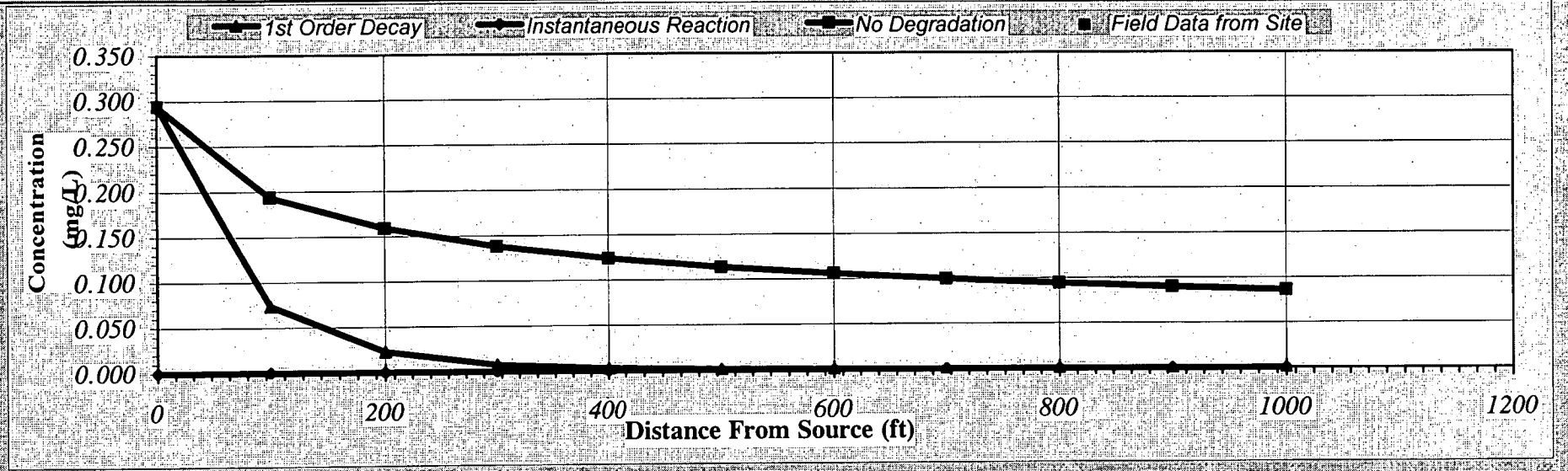
Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

Distance from Source (ft)

TYPE OF MODEL	0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.294	0.194	0.159	0.138	0.124	0.114	0.106	0.100	0.094	0.090	0.086
1st Order Decay	0.294	0.073	0.023	0.008	0.003	0.001	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

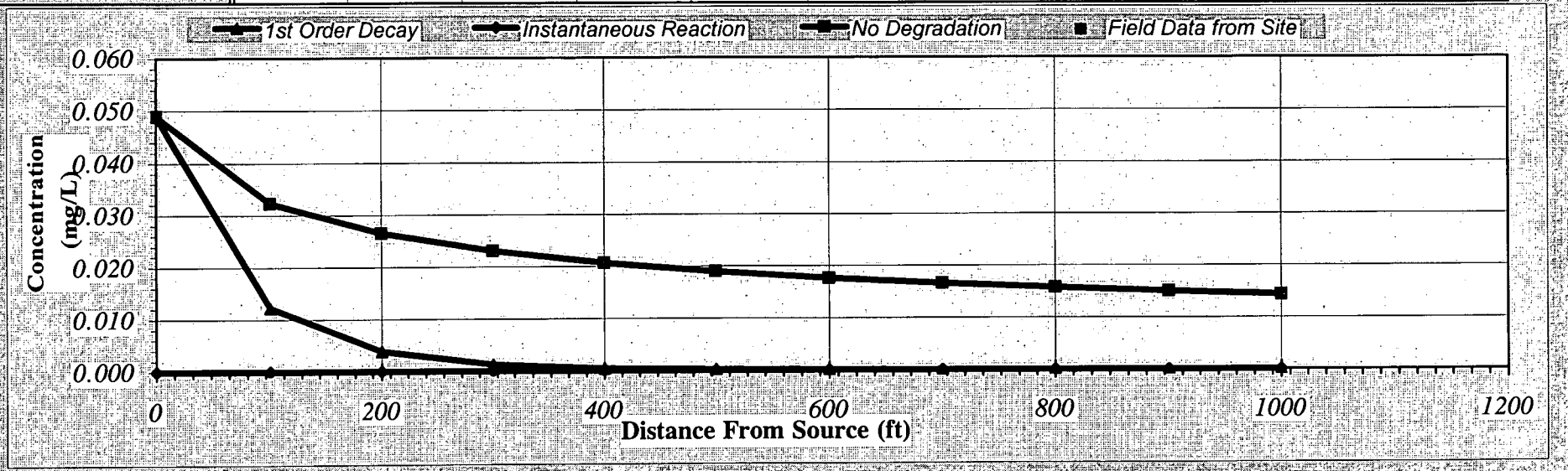
1,280 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.049	0.032	0.027	0.023	0.021	0.019	0.018	0.017	0.016	0.015	0.014
1st Order Decay	0.049	0.012	0.004	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Calculate Animation

Next Timestep

Prev Timestep

Time:

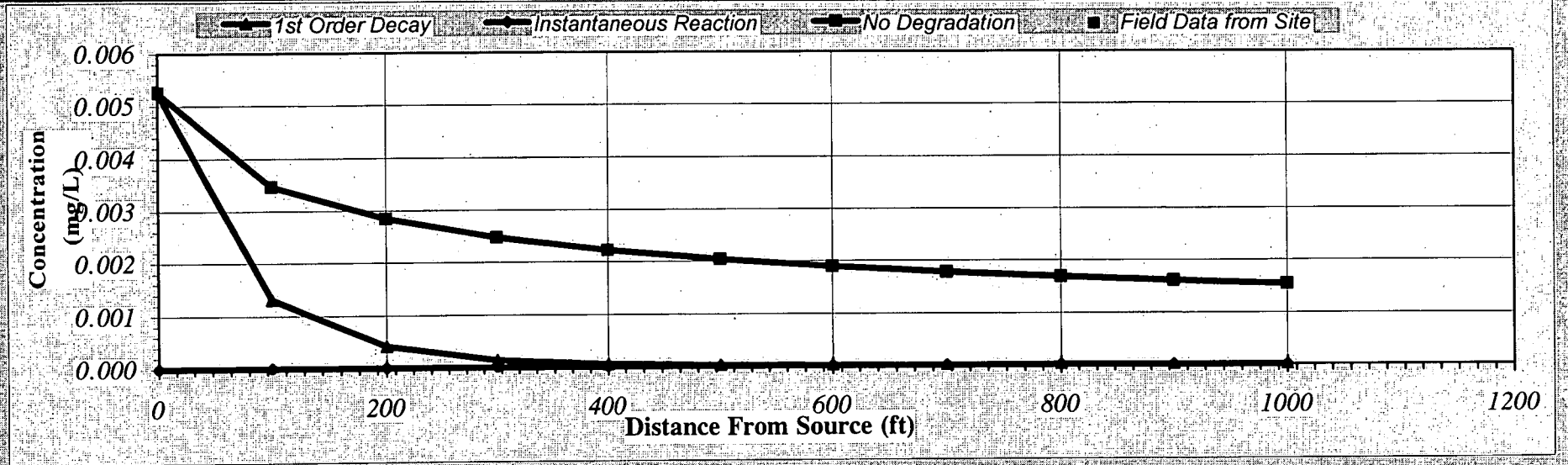
1,930 Years

Return to Input

Recalculate This Sheet

DISSOLVED HYDROCARBON CONCENTRATION ALONG PLUME CENTERLINE (mg/L at Z=0)

TYPE OF MODEL	Distance from Source (ft) 0	100	200	300	400	500	600	700	800	900	1000
No Degradation	0.005	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
1st Order Decay	0.005	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Inst. Reaction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Field Data from Site											



Time: 2,740 Years

Calculate Animation: Next Timestep / Prev Timestep

Return to Input

Recalculate This Sheet

Appendix D

Model Sensitivity Analysis

APPENDIX D

MODEL SENSITIVITY ANALYSIS

Plume and Contaminant Type	Input Parameter Version	Source Zone Depth (ft)	Hydraulic Gradient (ft/ft)	Porosity (-)	Seepage Velocity (ft/yr)	Instantaneous Reaction		1st Order Decay	
						Maximum Migration (ft)	Time to Source Depletion (yr)	Maximum Migration (ft)	Time to Source Depletion (yr)
TPH-GRO East	Original	3	0.0073	0.35	136.0	300	12	500	2,250
TPH-GRO East	MEDEP 1	3	0.0073	0.25	190.3	300	12	700	2,250
TPH-GRO East	MEDEP 2	3	0.01095	0.35	203.9	300	8	700	1,500
TPH-GRO East	MEDEP 3	3	0.01095	0.25	285.5	300	8	900	1,500
TPH-GRO East	MEDEP 4	5	0.0073	0.35	136.0	300	12	500	2,250
TPH-GRO East	MEDEP 5	5	0.0073	0.25	190.3	300	11	600	2,250
TPH-GRO East	MEDEP 6	5	0.01095	0.35	203.9	300	8	700	1,500
TPH-GRO East	MEDEP 7	5	0.01095	0.25	285.5	300	8	900	1,500
TPH-GRO West	Original	3	0.0073	0.35	136.0	300	9	500	6,100
TPH-GRO West	MEDEP 1	3	0.0073	0.25	190.3	400	9	600	6,100
TPH-GRO West	MEDEP 2	3	0.01095	0.35	203.9	300	6	600	4,100
TPH-GRO West	MEDEP 3	3	0.01095	0.25	285.5	400	6	900	4,100
TPH-GRO West	MEDEP 4	5	0.0073	0.35	136.0	300	9	500	6,100
TPH-GRO West	MEDEP 5	5	0.0073	0.25	190.3	400	9	600	6,100
TPH-GRO West	MEDEP 6	5	0.01095	0.35	203.9	300	6	600	4,100
TPH-GRO West	MEDEP 7	5	0.01095	0.25	285.5	400	6	900	4,100
TPH-DRO East	Original	3	0.0073	0.35	136.0	500	41	800	3,900
TPH-DRO East	MEDEP 1	3	0.0073	0.25	190.3	500	41	1,100	3,900
TPH-DRO East	MEDEP 2	3	0.01095	0.35	203.9	500	28	1,200	2,600
TPH-DRO East	MEDEP 3	3	0.01095	0.25	285.5	500	28	1,600	2,600
TPH-DRO East	MEDEP 4	5	0.0073	0.35	136.0	500	41	800	3,900
TPH-DRO East	MEDEP 5	5	0.0073	0.25	190.3	500	41	1,100	3,900
TPH-DRO East	MEDEP 6	5	0.01095	0.35	203.9	500	27	1,200	2,600
TPH-DRO East	MEDEP 7	5	0.01095	0.25	285.5	500	27	1,600	2,600
TPH-DRO West	Original	3	0.0073	0.35	136.0	800	29	800	2,750
TPH-DRO West	MEDEP 1	3	0.0073	0.25	190.3	1,000	29	1,100	2,750
TPH-DRO West	MEDEP 2	3	0.01095	0.35	203.9	800	19	1,200	1,900
TPH-DRO West	MEDEP 3	3	0.01095	0.25	285.5	1,000	19	1,600	1,850
TPH-DRO West	MEDEP 4	5	0.0073	0.35	136.0	800	29	800	2,750
TPH-DRO West	MEDEP 5	5	0.0073	0.25	190.3	1,100	29	1,100	2,750
TPH-DRO West	MEDEP 6	5	0.01095	0.35	203.9	800	19	1,200	1,850
TPH-DRO West	MEDEP 7	5	0.01095	0.25	285.5	900	19	1,600	1,850

Appendix E

Comments and EA's Response to Comments from the Maine Department of Environmental Protection on the Draft Report

February 10, 2003

Mr. Brian Helland
Code 1811/BH
Department of the Navy,
Engineering Field Activity-Northeast
Naval Facilities Engineering Command
10 Industrial Highway, Mail 82
Lester, PA 19113

Re: Old Fuel Farm-Bioscreen
Naval Air Station, Brunsick, Maine

Dear Mr. Helland:

The Maine Department of Environmental Protection (MEDEP) has reviewed the Navy's draft response to comments, dated December 30, 2002, prepared by EA Engineering, Science and Technology. Based on that review the Department has the following minor editing changes and one follow up comment that MEDEP would like included in this report.

General Comments:

1. The Department accepts the Navy's proposed new text as answering our concerns satisfactorily for Comments 6, 8 and 14a. The proposed text for Comments 7 and 10 require minor editing, as provided below.

2. **Comment 7:**

   "Therefore, the no-degradation model predictions provided by BIOSCREEN were not included for further consideration."

   To improve the factuality of this sentence MEDEP suggests the following: *"Therefore, the no-degradation model predictions provided by BIOSCREEN are not discussed further, but predicted trend lines are included in the Appendix B graphs for reference purposes only."*

3. **Comment 10:**

   The first sentence of the Navy's response stated that the last two sentences of Section 3.2.4.2 would be deleted. The last sentence (below) was not deleted.

   "The reduction coefficient was developed based on information provided with the BIOSCREEN R.1.4 user's manual."

   MEDEP yet believes that this statement does not reflect the customized approach that the Navy has applied. That is, instead of the manual recommended 30 percent reduction, the Navy applied a 70 percent reduction, which is more conservative. Please delete this sentence.

4. Comment 14b:

   MEDEP would not label the 3600 kg used by the Navy as "very conservative", due to uncertainty about whether the side-wall confirmation samples accurately represent remaining in-situ concentrations over a 6-foot depth interval (4 to 10 feet bgs), where in places, total TPH concentrations did exceed 1000 ppm before soil excavation.

   Nevertheless, a soluble mass of 3600 kg is accepted as being close enough to the actual unknown value for the purpose of comparing approximate decay-time scenarios. It is apparent that a doubling of the contaminated zone thickness using the same mass has little affect on BIOSCREEN predictions.

Thank you for the opportunity to review this report. If you have any questions or comments please call me at (207) 287-7713.

Respectfully,

Claudia Sait
Project Manager-Federal Facilities
Bureau of Remediation & Waste Management

Cf: File
Larry Dearborn-DEP
Anthony Williams-BNAS
Al Easterday-EA

RESPONSE TO COMMENTS ON THE NAVY'S RESPONSE TO COMMENTS FROM THE MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION ON THE DRAFT BIOSCREEN MODELING OF TOTAL PETROLEUM HYDROCARBONS REPORT DATED DECEMBER 2002 AT THE OLD NAVY FUEL FARM, NAVAL AIR STATION, BRUNSWICK MAINE

COMMENTOR: Claudia Sait **DATED: 10 February 2003**

The Maine Department of Environmental Protection (MEDEP) has reviewed the Navy's draft response to comments, dated 30 2002 December, prepared by EA Engineering, Science, and Technology. Based on that review, the Department has the following minor editing changes and one followup comment that MEDEP would like included in this report.

GENERAL COMMENTS

1. The Department accepts the Navy's proposed new text as answering our concerns satisfactorily for Comments 6, 8, and 14a. The proposed text for Comments 7 and 10 require minor editing, as provided below.

2. ***Comment 7***—*Therefore, the no-degradation model predictions provided by BIOSCREEN were not included for further consideration.*

   To improve the factuality of this sentence MEDEP suggests the following:

   Therefore, the no-degradation model predictions provided by BIOSCREEN are not discussed further, but predicted trend lines are included in the Appendix B graphs for reference purposes only.

   Response—Comment noted. The sentence in Section 3.2.4 has been revised as follows:

   Therefore, the no-degradation model predictions provided by BIOSCREEN are not discussed further, however, predicted trend lines are included on the graphs in Appendix B and Appendix C for reference purposes only.

3. ***Comment 10***—The first sentence of the Navy's response stated that the last two sentences of Section 3.2.4.2 would be deleted. The last sentence (below) was not deleted.

   The reduction coefficient was developed based on information provided with the BIOSCREEN R.1.4 user's manual.

   MEDEP yet believes that this statement does not reflect the customized approach that the Navy has applied. That is, instead of the manual recommended 30 percent reduction, the Navy applied a 70 percent reduction, which is more conservative. Please delete this sentence.

   Response—Comment noted. This sentence has been deleted from the final report.

4. ***Comment 14b***—MEDEP would not label the 3,600 kg used by the Navy as "very conservative," due to uncertainty about whether the side-wall confirmation samples accurately represent remaining *in-situ* concentrations over a 6-foot depth interval (4 to 10 feet bgs), where in places, total TPH concentrations did exceed 1000 ppm before soil excavation.

   Nevertheless, a soluble mass of 3,600 kg is accepted as being close enough to the actual unknown value for the purpose of comparing approximate decay-time scenarios. It is apparent that a doubling of the contaminated zone thickness using the same mass has little affect on BIOSCREEN predictions.

   Response—Comment noted. The Navy understands that MEDEP maintains the opinion that a residual soluble mass input parameter of 3,600 kg is sufficient, but not necessarily conservative for the BIOSCREEN natural attenuation model prepared for the Old Navy Fuel Farm.

STATE OF MAINE
DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF REMEDIATION AND WASTE MANAGEMENT, TECHNICAL SERVICES

MEMORANDUM

TO: Al Easterday, Project Manager-EA

FROM: Claudia Sait, Project Manager-MEDEP

DATE: December 30, 2002

SUBJECT: Comments on Navy's Responses on "Draft BIOSCREEN Modeling of Total Petroleum Hydrocarbons at the Old Navy Fuel Farm, Naval Air Station, Brunswick, Maine, May 2002"

General Comment 1:

The Department accepts all responses from the Navy as answering our concerns satisfactorily except for Comments 14 and 15.

The Navy states in their responses for MEDEP Comments 6, 7, and 8 that new text will be added to provide a better understanding of those subjects. Clarification in the report is also needed for Comment 10. It would avoid further comments if the State would like to review the new text prior to report finalization.

General Comment 2:

In the last paragraph of Comment 14, the Navy suggests that "further evaluation and potential modification of the BIOSCREEN model be considered after several years of ground-water monitoring data are available or immediately upon indication that ground-water analytical data significantly deviate from BIOSCREEN model predictions."

MEDEP endorses this proposal, and would like to develop with the Navy a consensus on what deviation would be termed significant.

Specific Comments 14 and 15:

In its response to Comment 14, the Navy provides the following conclusion: "The results of the sensitivity analysis have indicated no significant change to the BIOSCREEN model predictions".

a.) MEDEP views a 50 percent reduction in "Time to Source Depletion", shown by the model sensitivity analysis, as significant for DRO (between 10 to 13 years shorter), but perhaps is not significant for GRO (between 3 to 4 years). These reductions resulted from using the larger hydraulic gradient suggested by MEDEP as better representing documented site conditions. The model calculated times using the Navy's inputs is more conservative than calculated times using our suggested inputs. MEDEP would be satisfied if the Navy puts new text in that provides the ranges for "Time to Source Depletion".

b.) It is counterintuitive that expanding the source zone thickness from 3 feet to 5 feet did not affect source depletion times. Please check these model runs to validate that this was correctly implemented and then a brief conference call should be arranged to discuss this finding.

RESPONSE TO COMMENTS ON THE NAVY's RESPONSE TO COMMENTS FROM THE MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION ON THE DRAFT BIOSCREEN MODELING OF TOTAL PETROLEUM HYDROCARBONS REPORT DATED MAY 2002 AT THE OLD NAVY FUEL FARM NAVAL AIR STATION, BRUNSWICK MAINE

COMMENTOR: Claudia Sait **DATED: 30 December 2002**

GENERAL COMMENTS

The Department accepts all responses from the Navy as answering our concerns satisfactorily except for Comment Nos. 14 and 15.

The Navy states in their responses for MEDEP Comment Nos. 6, 7, and 8 that new text will be added to provide a better understanding of those subjects. Clarification in the report is also needed for Comment No. 10. It would avoid further comments if the State could review the new text prior to report finalization.

Response—The proposed text revisions for the Final BIOSCREEN report are provided below in response to MEDEP Comment Nos. 6, 7, 8, and 10.

Comment No. 6—The following text has been added between the last two paragraphs in Section 3.2.6—"Source Data."

The input source parameters used for the BIOSCREEN model were consistently selected to provide conservative baseline or "year zero" conditions. In the case of the year zero dissolved-phase TPH-GRO concentration in the eastern source area, a conservative value of 20 mg/L was used since LNAPL had previously been observed in this area.

It should be noted that the Navy has no indication that LNAPL continues to be present at the Old Navy Fuel Farm. The use of baseline dissolved-phase concentration input parameter values, which would otherwise be indicative of potential LNAPL presence, were applied for BIOSCREEN model analyses in an effort to assess the "worst-case" existing condition scenario, consistent with the overall intent of providing a conservative site model for the Old Navy Fuel Farm. There are no current data that would indicate the potential for LNAPL at the Old Navy Fuel Farm. The baseline dissolved-phase concentration input parameters were established solely to ensure that the BIOSCREEN model predictions were as conservative as possible.

Comment No. 7—The following text has been added after the first paragraph in Section 3.2.4— "Biodegradation."

In addition to the first-order decay and instantaneous reaction models, BIOSCREEN also provides a contaminant transport assessment based on a "no-degradation" model. The no-degradation model predicts the movement of contaminants in the ground water under the assumption that biodegradation does not occur within or downgradient to the source

area. The only attenuation mechanisms that are considered under the no-degradation model are dilution; dispersion in the longitudinal, transverse, and vertical directions; and adsorption of the contaminants to the soil.

Based on site-specific biodegradation indicator parameters previously assessed at the Old Navy Fuel Farm (including electron acceptor demand, microbial enumeration studies which quantified total heterotrophic and hydrocarbon degrading bacteria, and measurements of biodegradation by-products such as methane and carbon dioxide), it has been established that biodegradation of residual petroleum hydrocarbons has been occurring at the site. In addition, dissolved-phase contaminant trend data collected over a 10-year period (1991-2001) indicate that the no-degradation model is not applicable for predicting migration potential at the Old Navy Fuel Farm, since the actual extent of contaminant migration is far less than predicted under the no-degradation model. Therefore, the no-degradation model predictions provided by BIOSCREEN are not discussed further, however, predicted trend lines are included on the graphs in Appendix B for reference purposes only.

Comment No. 8—The following text has been added after the first paragraph in Section 2.3.4—"Post-Remedial Excavation Ground-Water Sampling."

During the December 2000 ground-water sampling event, dissolved-phase TPH-GRO was detected at only 2 of 14 monitoring well locations (MW-NASB-054 and MW-NASB-061R). Each of these monitoring wells was located within the Old Navy Fuel Farm fenceline in the vicinity of the western source area. Concentrations of dissolved-phase TPH-GROs reported at these locations during December 2000 ranged from 24 to 45 µg/L, each below the MEDEP stringent cleanup goal. During the December 2000, May 2001, and October 2001 ground-water sampling events, TPH-GRO was not detected at any upgradient or downgradient locations to the Old Navy Fuel Farm. During May and October 2001, ground-water samples were not collected from locations within the Old Navy Fuel Farm fenceline.

During the December 2000 and October 2001 ground-water sampling events, dissolved-phase TPH-DRO was not detected at monitoring well locations upgradient to the Old Navy Fuel Farm (including monitoring wells MW-NASB-062 and MW-NASB-213). These monitoring wells were not sampled during May 2001. Ground-water samples were collected from within the Old Navy Fuel Farm fenceline only during the December 2000 sampling event. Dissolved-phase TPH-DRO was detected at concentrations of 700 and 190 µg/L at monitoring wells MW-NASB-061R and MW-NASB-054, respectively. The relatively elevated TPH-DRO concentration reported at MW-NASB-061R was collected from the central region of the western source area.

During the December 2000, May 2001, and October 2001 ground-water sampling events, dissolved-phase TPH-DRO was detected at concentrations ranging from non-detect to 400 µg/L at several monitoring wells located downgradient to the Old Navy Fuel Farm. As discussed previously, TPH-GRO was not reported at these locations. Migration of ppb concentrations of TPH-DRO to the downgradient monitoring wells may have occurred since TPH-GRO within the source area was likely preferentially biodegraded relative to TPH-DRO compounds.

Comment No. 10—The last two sentences of the last paragraph of Section 3.2.4.2 ("Instantaneous Reaction Model") has been deleted. The following text has been added at the end of Section 3.2.4.2.

> *To provide a conservative approximation of TPH-DRO biodegradation relative to TPH-GRO biodegradation, the Navy applied a reduction coefficient of 0.3 to the TPH-GRO electron acceptor availability/biodegradation indicator input parameters (i.e., multiplied the TPH-GRO biodegradation indicator parameter concentrations by 0.3 for a 70 percent overall reduction in the corresponding input parameter values). This step was taken to account for the reduced biodegradation rate of TPH-DRO compounds relative to TPH-GRO compounds as well as to account for the competitive degradation requirements of DRO compounds in the presence of GRO compounds. During the model calibration process, site-specific analytical trend data were used to select and support the 0.3 reduction coefficient.*

Last Paragraph of Comment No. 14—The Navy suggests that "further evaluation and potential modification of the BIOSCREEN model be considered after several years of ground-water monitoring data are available or immediately upon indication that ground-water analytical data significantly deviate from BIOSCREEN model predictions.

MEDEP endorses this proposal, and would like to develop with the Navy a consensus on what deviation would be termed significant.

Response—Agree. A conference call or meeting should be held between the Navy and MEDEP to define what ground-water monitoring data would represent a "deviation" from the BIOSCREEN model predictions. Resolution of this comment and response should not impact the finalization of the BIOSCREEN report.

SPECIFIC COMMENTS

Response to Comment No. 14—The Navy provides the following conclusion: "The results of the sensitivity analysis have indicated no significant change to the BIOSCREEN model predictions."

a. MEDEP views a 50 percent reduction in "Time to Source Depletion," shown by the model sensitivity analysis, as significant for DRO (between 10 and 13 years shorter), but perhaps is not significant for GRO (between 3 and 4 years). These reductions resulted from using the larger hydraulic gradient suggested by MEDEP as better representing documented site conditions. The model calculated times using the Navy's inputs are more conservative than calculated times using our suggested inputs. MEDEP would be satisfied if the Navy puts new text in that provides the ranges for "Time to Source Depletion."

   Response—Comment noted. The Navy has added a discussion of the range in the predicted "Time to Source Depletion" as requested. This text is provided below and has been added to the BIOSCREEN report in Section 5.3:

The model sensitivity analysis indicated that increasing the hydraulic gradient from 0.0073 to 0.01095 ft/ft resulted in a reduction of approximately 50 percent in the estimated time to TPH-DRO source depletion. Based on the model sensitivity analysis, the estimated time to source depletion for TPH-DRO ranged from 27 to 41 years for the eastern source area and from 19 to 29 years for the western source area, with the longer time to source depletion estimates associated with the lower hydraulic gradient input parameter value. It is apparent that increasing the hydraulic gradient results in a decreased time for TPH-DRO source depletion as a result of increased contaminant dispersion rate, with an associated increased rate of natural attenuation. A similar effect was noted for the TPH-GRO models, although to a lesser degree since the original time to source depletion estimates was significantly less than corresponding estimates for TPH-DRO range compounds.

b. It is counterintuitive that expanding the source zone thickness from 3 ft to 5 ft did not affect source depletion times. Please check these model runs to validate that this was correctly implemented and then a brief conference call should be arranged to discuss this finding.

Response—Comment noted. Reference previous response to Comment No. 11. Following the 1999 remedial soil excavation program which included removal of source zone soils containing >850 mg/kg of petroleum hydrocarbons, significant source zone soil contamination is not believed to remain at the Old Navy Fuel Farm. However, to provide the most conservative model input parameters, the Navy assumed a "worst-case" scenario that included approximately 3,600 kg of petroleum hydrocarbons present as soluble mass in the source zone. This soluble mass was previously assessed under the assumption of a 3-ft source zone thickness, based on historical ground-water elevation data and field observations reported during the 1999 remedial soil excavation program. In response to MEDEP Comment No. 11, the Navy completed a model sensitivity analysis that increased the source zone thickness from 3 to 5 ft. However, the original soluble mass estimate, which is believed to have been very conservative, was applied over the 5-ft source zone. The sensitivity analysis indicated that increasing the source zone thickness with the original soluble mass estimate made no significant change to the model predictions.

STATE OF MAINE
DEPARTMENT OF ENVIRONMENTAL PROTECTION

ANGUS S. KING, JR.
GOVERNOR

MARTHA KIRKPATRICK
COMMISSIONER

July 22, 2002

Mr. Brian Helland
Code 1811/BH
Department of the Navy,
Engineering Field Activity-Northeast
Naval Facilities Engineering Command
10 Industrial Highway, Mail 82
Lester, PA 19113

Re: BIOSCREEN Modeling-Old Navy Fuel Farm
Naval Air Station, Brunswick

Dear Mr. Helland:

The Maine Department of Environmental Protection (MEDEP or Department) has reviewed the document entitled Draft BIOSCREEN Modeling of Total Petroleum Hydrocarbons at the Old Navy Fuel Farm, dated May 2002, prepared by EA Engineering, Science and Technology. Based on that review the Department has the following comments and issues.

General Comments

1. The Department appreciates the amount of effort the Navy has expended in modeling the existing site chemical data spanning from 1990 to 2001, per the July 11, 2001 meeting recommendation. Upon reviewing the analyses presented in the report, a few questions need to be answered before the State can accept the model predictions in regards to persistence of the dissolved-phase plume. However, the general range of the predicted timeframes is within the expected realm. These outstanding concerns are addressed individually under "Specific Comments".

2. MEDEP agrees that 10 years of site groundwater sampling data support the Navy's interpretation of model output that the dissolved-phase plume has reached its maximum downgradient extent, and may be pulling back toward the source area as a result of biodegradation.

3. The Navy states in several places within the report that the biodegradation modeling (using the BIOSCREEN 2-dimensional groundwater flow and transport method) was used with conservative input values that reflect site conditions. In most instances, this appears true. Inputs that may not be conservative are:
   - Porosity;
   - the 3-foot thick source zone and
   - the reduction coefficient of 0.3 applied to DRO modeling.

   Please either provide your rationale to why your inputs are considered conservative or run the model with the more conservative inputs, as noted below.

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4. The present-day distribution of DRO in groundwater monitoring wells appears to agree with model predictions. The instantaneous reaction biodegradation model predicted that after 18 years the DRO concentration at a distance of 800 feet downgradient would be 300 µg/L. Although the timeframe may be off a few years, in May 2001, a DRO concentration of 400 µg/L was measured at MW-NASB-208 approximately 800 feet from the source (Figure 9). The value of 117 µg/L was measured in October 2001 at MW-NASB-245, another 100 feet farther downgradient, and provides supporting evidence. (No response required.)

5. Results from the 1st order decay model show extremely long degradation times that are discounted for valid reasons. Perhaps there is no net value that would justify including this model in the report. Please consider deleting the 1st order decay graphs, condensing the report.

6. No where in the text of the report is there mention of LNAPL, past or currently. However, footnote (c) of Table 3 reads: "Based on site-specific analytical data, the dissolved-phase total BTEX concentration in areas exhibiting LNAPL is assumed to be >20,000 µg/L. Initial (i.e., year zero) model source area concentration assumed to be 25,000 µg/L."

   If LNAPL is believed to exist it needs to be discussed in the test, please correct this deficiency.

7. The appendices contain many graphs showing the projected rate of decay of dissolved-phase petroleum hydrocarbon over time under three headings: 1st order decay, instantaneous reaction, and no degradation. The first two are discussed in detail, however, there appears to be no discussion of the no-degradation trend lines in the report. The graph legend would seem to indicate that these trend lines are field-data based. But these projections extend for hundreds, and even thousands, of years. MEDEP suspects that no-degradation lines are BIOSCREEN's predictions if only dilution, dispersion, and adsorption processes are activated. Please add a new subsection to the report to explain "no degradation trends lines".

Specific Comments:

8. Section 2.3.4, Post-Remedial Excavation Ground-Water Sampling, p. 5:

   Unlike the preceding sections that summarize remedial programs conducted at the Old Fuel Farm, the results of analytical sampling are not discussed at all, except to reference three tag map figures. It would be helpful to add a paragraph on the findings.

9. Section 3.1, Source Areas and Dissolved-Phase Hydrocarbon Plumes, p. 6, 2nd para:

   The first sentence notes that the most recent sampling event upon which to base GRO and DRO plume delineation is June 1999. This is three years prior to the report being finalized. MEDEP realizes that a number of monitoring wells in the area were decommissioned (removed) to perform remedial work at the Old Fuel Farm. An adequate monitoring network of wells for a Long Term Monitoring Program, approved by MEDEP, will be needed for long-term confirmation of biodegradation progress.

10. Section 3.2.4.2, Instantaneous Reaction Model, p. 11, next to bottom para:

    "...a reduction coefficient of 0.3 was applied to the natural attenuation parameter data used for the TPH-DRO simulations. This reduction coefficient was developed based on information provided with the BIOSCREEN R.1.4 user's manual."

The manual reads: "If these data are not available [TOC and BOD], a conservative approach would be to reduce all available electron acceptor/by-product concentrations used in the model by 30% to account for the possible impacts of non-BTEX organics in groundwater."

It is not clear if the Navy's "reduction coefficient of 0.3" is the same as reducing concentrations by 30%. A coefficient normally implies a multiplication process. As such, the new concentrations would be 30% of the original concentrations; however, the manual's intent is a value of 70% of the original concentration. If the Navy used the lower concentration of electron acceptors (30%, not 70%), the predicted years of biodegradation to 50 µg/L TPH-DRO would be too large. Please check your calculations, correct if appropriate, and clarify the above text.

11. Section 3.2.6, Source Data, p. 12, 2nd para:

"The photoionization detector/flame ionization detector field screening data results indicate that soils from 3 to 6 ft below ground surface contained the most elevated concentrations of petroleum hydrocarbons across the site."

In deriving the contaminant mass to be degraded, more thickness of the contaminated soil than just that containing the most elevated concentrations is applicable. Therefore, MEDEP questions reference to the applied 3 feet of source zone thickness as being conservative. The BIOSCREEN User's Manual, under "6. Source Data" gives a typical value range as 5 to 50 feet. It also describes estimating the thickness of the smear zone for water-table fluctuation data - a supporting approach the Navy mentions . MEDEP recommends that a value 5 feet be used if a conservative value is desired, as the highest and lowest water levels after the fuel release(s) occurred is unknown (monitoring frequency too sparse), and concentrations less that the most elevated but yet significant apparently occur over a thicker zone.

12. Section 4.3, Calibration Procedures for Modeling..., p. 15, bottom para, and p.16 top para:

It is difficult to clearly understand the relationships mentioned with regards to the results of the 6-year calibration period. The text needs to be supported by a figure or graph. Was it good fortune that the calibration period was just 6 years long, and would different relationships between the 1st order decay model and the instantaneous reaction model have resulted from a longer calibration period?

13. Section 5.1, Total Petroleum Hydrocarbon-Gasoline Range Organics, p. 17, bottom para:

"Data summary Tables 5 and 6 include indications of time periods for which predicted downgradient plume concentrations are considered to be less than actual."

Therefore, the assumption of zero initial downgradient concentrations apparently introduces a complication that causes the instantaneous reaction model predictions of concentrations to be too low, and therefore, not conservative. How serious is this effect on the Navy's claim that the modeling results are overall quite conservative?

14. Section 5.3, Conclusions, p. 21, 1st para:

"Therefore, the resulting model predictions for the persistence and migration potential of dissolved-phase petroleum hydrocarbons at the Old Fuel Farm should be viewed as a worst-case scenario."

Prior to addressing the above comments that relate to degree of conservatism, this claim is not endorsed by MEDEP. Perhaps the Navy would want to offer two results scenarios: one that is truly conservative per MEDEP's suggestions and another that reflects the most likely value for each input into the instantaneous reaction model. The differences in migration and persistence between the two cases could then be assessed for significance.

15. Table 2, Bioscreen Model Input parameter Summary:

Porosity (n) should be relabeled "Effective Porosity (n_e)". MEDEP recommends that a value of 0.25 be used, which is more inline with the sand and silty sand composition of the contaminated overburden.

Also, our analysis of the water-table contour map (Figure 3) produced hydraulic gradients that generally are between 0.009 and 0.02. A value around 50 percent higher than now used as input (0.0073 ft/ft) may be more representative.

16. Table 6, Bioscreen Modeling Results from Instantaneous Reaction Simulation...:

According to the notes, the maximum concentration of TPH-DRO used in the simulation is 10,000 µg/L. In Table 2, under Source Data, a value of 20 mg/L is given for the eastern TPH-DRO plume. It appears as the latter value is correct. Please correct the note and modeled times (if necessary). Also, check on the first page of Appendix C and determine if the 10 mg/L is correct for the DRO-east prediction

Also, the (a) and (b) footnotes do not correlate properly with notations in the body of the table.

17. Table 7, Bioscreen Modeling Results from First-Order Decay Simulation...:

Same situation as the first part of the above comment 16.

Thank you for the opportunity to review this report. If you have any questions or want to set up a conference call or meeting to discuss these comments please call me at (207) 287-7713.

Respectfully,

Claudia Sait

Claudia Sait
Project Manager-Federal Facilities
Bureau of Remediation & Waste Management

Cf: File
Larry Dearborn-DEP
Anthony Williams-BNAS
Al Easterday-EA Engineering

RESPONSE TO COMMENTS FROM THE MAINE DEPARTMENT OF ENVIRONMENTAL PROTECTION ON THE DRAFT BIOSCREEN MODELING OF TOTAL PETROLEUM HYDROCARBONS REPORT DATED MAY 2002 AT THE OLD NAVY FUEL FARM, NAVAL AIR STATION, BRUNSWICK MAINE

COMMENTOR: Claudia Sait **DATED: 22 July 2002**

GENERAL COMMENTS

1. The Department appreciates the amount of effort the Navy has expended in modeling the existing site chemical data spanning from 1990 to 2001, per the July 11, 2001 meeting recommendation. Upon reviewing the analyses presented in the report, a few questions need to be answered before the State can accept the model predictions in regards to persistence of the dissolved-phase plume. However, the general range of the predicted timeframes is within the expected realm. These outstanding concerns are addressed individually under "Specific Comments."

   Response—Comment noted. The Navy appreciates MEDEP's observation of the significant effort expended to develop the model for the Old Navy Fuel Farm to support monitored natural attenuation of this site. The model was developed with conservative input parameters that were explained throughout the text of the report and which are supported by historical analytical trend data collected at the site over a 10-year period. MEDEP has stated in several of the following comments that specific input parameters may not be conservative, and/or have suggested alternate input parameter values. In an effort to assess the effect of altering the input parameters as suggested by MEDEP, the Navy has completed a sensitivity analysis to demonstrate the net change to BIOSCREEN model predictions using the suggested input parameters as specified in MEDEP Comment Nos. 3, 11, 14, and 15. As indicated in the attached model sensitivity analysis (Attachment A), use of the alternate input parameter values suggested by MEDEP (i.e., using each suggested input parameter modification alone and all possible combinations with other suggested input parameter modifications) resulted in no significant change to the model predictions (reference detailed analyses in specific comment responses). Since MEDEP has agreed with the overall prediction of the BIOSCREEEN model as provided with the draft report (i.e., the plumes have reached steady-state and are gradually degrading as a result of biodegradation—reference General Comment No. 2), the Navy proposes to include this response document with the sensitivity analysis as an appendix to the model and report, and continue to use the model input parameters included with the draft report since the Navy believes the existing input parameters are valid, defendable, and conservative.

2. MEDEP agrees that 10 years of site groundwater sampling data support the Navy's interpretation of model output that the dissolved-phase plume has reached its maximum downgradient extent, and may be pulling back toward the source area as a result of biodegradation.

   Response—Comment noted.

3. The Navy states in several places within the report that the biodegradation modeling (using the BIOSCREEN 2-dimensional groundwater flow and transport method) was used with conservative input values that reflect site conditions. In most instances, this appears true. Inputs that may not be conservative are:

    - Porosity
    - The 3-foot thick source zone and the reduction coefficient of 0.3 applied to DRO modeling
    - Please either provide your rationale to why your inputs are considered conservative or run the model with the more conservative inputs, as noted below.

    Response—Comment noted. Reference response to General Comment No. 1. Specific input parameter modifications and corresponding model sensitivity analyses are addressed with the Specific Comment responses, provided below.

4. The present-day distribution of DRO in groundwater monitoring wells appears to agree with model predictions. The instantaneous reaction biodegradation model predicted that after 18 years the DRO concentration at a distance of 800 feet downgradient would be 300 µg/L. Although the timeframe may be off a few years, in May 2001, a DRO concentration of 400 µg/L was measured at MW-NASB-208 approximately 800 feet from the source (Figure 9). The value of 117 µg/L was measured in October 2001 at MW-NASB-245, another 100 feet farther downgradient, and provides supporting evidence. (No response required.)

    Response—Comment noted.

5. Results from the 1st order decay model show extremely long degradation times that are discounted for valid reasons. Perhaps there is no net value that would justify including this model in the report. Please consider deleting the 1st order decay graphs, condensing the report.

    Response—Comment noted. The Navy agrees that the first-order decay model predicts extremely long (i.e., unrealistic) degradation times because the model does not consider biodegradation within the source area. However, the first-order decay model remains appropriate for providing a conservative prediction of dissolved-phase plume migration potential at the Old Navy Fuel Farm site and should remain within the report to support the migration potentials predicted under the instantaneous reaction model.

6. No where in the text of the report is there mention of LNAPL, past or currently. However, footnote (c) of Table 3 reads: "Based on site-specific analytical data, the dissolved-phase total BTEX concentration in areas exhibiting LNAPL is assumed to be >20,000 µg/L. Initial (i.e., year zero) model source area concentration assumed to be 25,000 µg/L."

    If LNAPL is believed to exist it needs to be discussed in the test, please correct this deficiency.

    Response—Comment noted. The Navy has no indication that LNAPL continues to be present at the Old Navy Fuel Farm. The use of baseline dissolved-phase concentration input parameter values, which would otherwise be indicative of potential LNAPL presence, were

applied for BIOSCREEN model analyses in an effort to assess the 'worst-case' existing condition scenario, consistent with the overall intent of providing a conservative site model for the Old Navy Fuel Farm.

The report text has been modified to clarify that there are no data which would indicate the current potential for LNAPL at the Old Navy Fuel Farm and that the baseline dissolved-phase concentration input parameters were established solely to ensure that the BIOSCREEN model predictions were as conservative as possible. See Response to Comments dated 30 December 2002.

7. The appendices contain many graphs showing the projected rate of decay of dissolved-phase petroleum hydrocarbon over time under three headings: 1st order decay, instantaneous reaction, and no degradation. The first two are discussed in detail, however, there appears to be no discussion of the no-degradation trend lines in the report. The graph legend would seem to indicate that these trend lines are field-data based. But these projections extend for hundreds, and even thousands, of years. MEDEP suspects that no-degradation lines are BIOSCREEN's predictions if only dilution, dispersion, and adsorption processes are activated. Please add a new subsection to the report to explain "no degradation trends lines."

   Response—BIOSCREEN generates three model types: (1) contaminant transport without decay (no-degradation); (2) contaminant transport with first-order decay representing biodegradation downgradient to the source area (first-order decay); and (3) contaminant transport with degradation modeled as an "instantaneous" reaction based on the availability of electron acceptors, including biodegradation within and downgradient to the source area. The no-degradation model predicts the movement of contaminants in the ground water under the assumption that biodegradation does not occur within or downgradient to the source area. The only attenuation mechanisms that are considered under the no-degradation model are dilution; dispersion in the longitudinal, transverse, and vertical directions; and adsorption of the contaminants to the soil.

   Based on site-specific biodegradation indicator parameters previously assessed at the Old Navy Fuel Farm (including electron acceptor demand, microbial enumeration studies which quantified total heterotrophic and hydrocarbon degrading bacteria, and measurements of biodegradation by-products such as methane and carbon dioxide), it has been established that biodegradation of residual petroleum hydrocarbons has been occurring at the site. In addition, dissolved-phase contaminant trend data collected over a 10-year period (1991-2001) indicate that the no-degradation model is not applicable for predicting migration potential at the Old Navy Fuel Farm, since the actual extent of contaminant migration is far less than predicted under the no-degradation model. Text has been added to the report to clarify that the no-degradation model is not applicable and should not be considered when assessing the BIOSCREEN model predictions for the Old Navy Fuel Farm. See Response to Comments dated 30 December 2002.

SPECIFIC COMMENTS

8. ***Section 2.3.4, Post-Remedial Excavation Ground-Water Sampling, Page 5***—Unlike the preceding sections that summarize remedial programs conducted at the Old Fuel Farm, the results of analytical sampling are not discussed at all, except to reference three tag map figures. It would be helpful to add a paragraph on the findings.

   Response—A paragraph has been added to summarize the analytical data of the sampling events presented in the three tag maps and to make this section of the report similar to the previous sections that summarize the remedial programs completed at the Old Navy Fuel Farm. See Response to Comments dated 30 December 2002.

9. ***Section 3.1, Source Areas and Dissolved-Phase Hydrocarbon Plumes, Page 6, 2nd Paragraph***—The first sentence notes that the most recent sampling event upon which to base GRO and DRO plume delineation is June 1999. This is three years prior to the report being finalized. MEDEP realizes that a number of monitoring wells in the area were decommissioned (removed) to perform remedial work at the Old Fuel Farm. An adequate monitoring network of wells for a Long Term Monitoring Program, approved by MEDEP, will be needed for long-term confirmation of biodegradation progress.

   Response—Comment noted. Once the MEDEP has accepted the BIOSCREEN model and report, the Navy anticipates meeting with MEDEP to discuss the monitoring well network at the Old Navy Fuel Farm to determine if the network is adequate for monitoring the biodegradation process and discuss long-term monitoring program requirements at the Old Navy Fuel Farm.

10. ***Section 3.2.4.2, Instantaneous Reaction Model, Page 11, next to Bottom Paragraph***—...a reduction coefficient of 0.3 was applied to the natural attenuation parameter data used for the TPH-DRO simulations. This reduction coefficient was developed based on information provided with the BIOSCREEN R.1.4 user's manual. The manual reads: "If these data are not available [TOC and BOD], a conservative approach would be to reduce all available electron acceptor/by-product concentrations used in the model by 30% to account for the possible impacts of non-BTEX organics in groundwater."

    It is not clear if the Navy's "reduction coefficient of 0.3" is the same as reducing concentrations by 30%. A coefficient normally implies a multiplication process. As such, the new concentrations would be 30% of the original concentrations; however, the manual's intent is a value of 70% of the original concentration. If the Navy used the lower concentration of electron acceptors (30%, not 70%), the predicted years of biodegradation to 50 µg/L TPH-DRO would be too large. Please check your calculations, correct if appropriate, and clarify the above text.

    Response—To provide a conservative approximation of TPH-DRO biodegradation relative to TPH-GRO biodegradation, the Navy applied a reduction coefficient of 0.3 to the TPH-GRO electron acceptor availability/biodegradation indicator input parameters (i.e., multiplied the TPH-GRO biodegradation indicator parameter concentrations by 0.3 for a 70 percent overall reduction in the corresponding input parameter values). This step was taken to account for the reduced biodegradation rate of TPH-DRO compounds relative to TPH-GRO

compounds as well as to account for the competitive degradation requirements of DRO compounds in the presence of GRO compounds. During the model calibration process, site-specific analytical trend data were used to select and support the 0.3 reduction coefficient.

11. ***Section 3.2.6, Source Data, Page 12, 2nd Paragraph***—The photoionization detector/flame ionization detector field screening data results indicate that soils from 3 to 6 ft below ground surface contained the most elevated concentrations of petroleum hydrocarbons across the site. In deriving the contaminant mass to be degraded, more thickness of the contaminated soil than just that containing the most elevated concentrations is applicable. Therefore, MEDEP questions reference to the applied 3 feet of source zone thickness as being conservative. The BIOSCREEN User's Manual, under "6. Source Data" gives a typical value range as 5 to 50 feet. It also describes estimating the thickness of the smear zone for water-table fluctuation data - a supporting approach the Navy mentions . MEDEP recommends that a value 5 feet be used if a conservative value is desired, as the highest and lowest water levels after the fuel release(s) occurred is unknown (monitoring frequency too sparse), and concentrations less that the most elevated but yet significant apparently occur over a thicker zone.

    Response—Comment noted. The use of a 3-ft source zone thickness was based on historical ground-water elevation data and was considered to be conservative since the 1999 remedial soil excavation program was completed to remove soil containing >850 mg/kg of petroleum hydrocarbons from the Old Navy Fuel Farm site. Therefore, the continued presence of any significantly contaminated smear zone is considered to be unlikely, based on confirmatory soil sampling data. To ensure that the model was developed with conservative baseline site conditions, the Navy assumed significantly greater smear zone contamination than is likely to be present at the Old Navy Fuel Farm.

    As indicated by the attached model sensitivity analysis, which utilized a 5-ft source zone thickness for both the TPH-GRO and TPH-DRO models as suggested by MEDEP, the maximum extent of dissolved TPH-GRO and TPH-DRO migration and years to source depletion were not changed relative to the 3-ft source zone thickness, under the same conservative contaminant mass input values.

12. ***Section 4.3, Calibration Procedures for Modeling..., Page 15, bottom Paragraph, and Page 16 Top Paragraph***—It is difficult to clearly understand the relationships mentioned with regards to the results of the 6-year calibration period. The text needs to be supported by a figure or graph. Was it good fortune that the calibration period was just 6 years long, and would different relationships between the 1st order decay model and the instantaneous reaction model have resulted from a longer calibration period?

    Response—Comment noted. As a general response to model calibration questions for the Old Navy Fuel Farm site, it should first be noted that the source of petroleum hydrocarbon contamination is related to historical bulk petroleum storage and distribution activities, which took place from 1951 to 1993. Since the first available set of ground-water sampling data is from 1990 and since multiple release events are likely to have taken place during the period prior to 1990, it is not possible to quantify the specific age of residual petroleum hydrocarbon contamination at the site. However, it is a reasonable assumption that petroleum hydrocarbon releases have occurred since at least the 1950s or 1960s.

Based on ground-water sampling data collected since 1990, it has been established that the dissolved-phase hydrocarbon plumes have reached steady-state and appear to be withdrawing toward the source areas within the Old Navy Fuel Farm fenceline (reference supporting MEDEP General Comment No. 2). Therefore, when calibrating the BIOSCREEN models, the user must ensure that predictions of potential dissolved-phase contaminant migration do not exceed the limits established by the site history. In other words, the model calibration process must account for the fact that the hydrocarbon plumes have reached steady state.

A 6-year calibration period (1990-1996) was available for assessing the BIOSCREEN first-order decay and instantaneous reaction model predictions against actual contaminant behavior based on the existing ground-water sampling data collected prior to active remedial system operations. The model predictions are evaluated against actual ground-water sampling data over the 6-year period in Table 3 of the report. For both models, the same site-specific physical/geological input values were fixed prior to model calibration. The known site behavior during the period 1990-1996 was then used to set the biodegradation input parameters for the first-order decay and instantaneous reaction models. Once the models were both calibrated to the established site history, the biodegradation input parameters were re-evaluated to ensure that they were consistent with site-specific data or, in lieu of site-specific information, were within acceptable ranges for similar sites.

MEDEP raises an excellent point with regard to the model calibration period. It is true that if the model calibration period had been significantly different (i.e., 15 or 20 years, as opposed to 6 years), the biodegradation input parameters may have been set at slightly different values to fit the model predictions to the known site history. Therefore, slightly different predictions based on current site conditions may have resulted. However, since the models were calibrated within typical limits for similar sites, and since the calibrated models were consistent with known site history prior to active remediation, the Navy believes that the model output provided with the draft report remains within the range of expectation for both contaminant migration potential and time to source depletion. It should also be stressed that the baseline or year zero conditions were conservative, in particular with respect to the existing mass of residual contamination which was assumed to be a worst-case scenario, essentially neglecting much of the soil removal action completed in 1999.

13. ***Section 5.1, Total Petroleum Hydrocarbon-Gasoline Range Organics, Page 17, bottom Paragraph***—Data summary Tables 5 and 6 include indications of time periods for which predicted downgradient plume concentrations are considered to be less than actual. Therefore, the assumption of zero initial downgradient concentrations apparently introduces a complication that causes the instantaneous reaction model predictions of concentrations to be too low, and therefore, not conservative. How serious is this effect on the Navy's claim that the modeling results are overall quite conservative?

Response— Comment noted. One of the limitations of the BIOSCREEN model is that the user cannot establish downgradient contaminant concentrations (beyond the source area) at year zero. To account for this limitation, the Navy applied conservative baseline dissolved-phase and sorbed-phase concentrations within the source areas (reference response to General Comment No. 6). In addition, the models were calibrated to ensure that downgradient migration potential was consistent with the known site history, as discussed

above. Essentially, the potential risk of not including residual (i.e., ppb level) dissolved-phase contaminant concentrations at downgradient locations during year zero can be expressed as the risk that such residual contaminants would pose if all source area contamination (sorbed and dissolved-phase) were to be eliminated at year zero. It is believed that in this scenario, the residual ppb level dissolved-phase contaminants located downgradient of the Old Navy Fuel Farm fenceline would be reduced to non-detect concentrations in several years and would not migrate beyond year zero distances. The model remains conservative since the source area contaminant concentrations at year zero were assumed to be significantly greater than actual data indicate.

14. ***Section 5.3, Conclusions, Page 21, 1st Paragraph***—Therefore, the resulting model predictions for the persistence and migration potential of dissolved-phase petroleum hydrocarbons at the Old Fuel Farm should be viewed as a worst-case scenario. Prior to addressing the above comments that relate to degree of conservatism, this claim is not endorsed by MEDEP. Perhaps the Navy would want to offer two results scenarios: one that is truly conservative per MEDEP's suggestions and another that reflects the most likely value for each input into the instantaneous reaction model. The differences in migration and persistence between the two cases could then be assessed for significance.

    Response—Comment noted. The referenced model sensitivity analysis is provided in Attachment A.

    As discussed above and as MEDEP has agreed, the residual hydrocarbon plume(s) at the Old Navy Fuel Farm have reached steady state and appear to be withdrawing to the source area. Therefore, it is understood that the BIOSCREEN model results, which predict no further migration of dissolved-phase contaminants, are consistent with the established site history.

    The Navy has performed a sensitivity analysis using each of the suggested input parameter modifications alone and in combination with other suggested input parameter modifications. The results of the sensitivity analysis have indicated no significant change to the BIOSCREEN model predictions.

    The Navy continues to support the BIOSCREEN model as calibrated and run in the draft report. Since the Navy intends to conduct a long-term monitoring program at the Old Navy Fuel Farm, it is suggested that further evaluation and potential modification of the BIOSCREEN model be considered after several years of ground-water monitoring data are available or immediately upon indication that ground-water analytical data significantly deviate from BIOSCREEN model predictions.

15. ***Table 2, Bioscreen Model Input parameter Summary***—Porosity (n) should be relabeled "Effective Porosity (n_e)." MEDEP recommends that a value of 0.25 be used, which is more inline with the sand and silty sand composition of the contaminated overburden. Also, our analysis of the water-table contour map (Figure 3) produced hydraulic gradients that generally are between 0.009 and 0.02. A value around 50 percent higher than now used as input (0.0073 ft/ft) may be more representative.

Response—Comment noted. Porosity (n) has been relabeled "effective porosity (n_e)" as requested.

The porosity value (0.35) used for BIOSCREEN modeling of the Old Navy Fuel Farm site was obtained from site-specific values presented in the 1992 Remedial Investigation Report (O'Brien & Gere) as well as other published sources of porosity values such as Fetter (porosity values for sand and gravel – 20-35 percent, and silt 35-50 percent) and Freeze and Cherry (sand – 25-50 percent, and silt 35-50 percent). The porosity value was also within the typical range provided with the BIOSCREEN User's Manual (Version 1.4) for the overburden type at the Old Navy Fuel Farm.

As indicated by the attached sensitivity analysis, reducing the porosity input value from 0.35 to 0.25 produces no change to the instantaneous reaction model predictions (maximum migration and years to source depletion) for the eastern GRO and DRO plumes. A similar modification of the porosity input value produces a slight increase in the predicted maximum extent of migration (ft) for GRO and DRO compounds under the instantaneous reaction and first-order decay models. However, it should be noted that only trace level dissolved-phase hydrocarbon concentrations are predicted at downgradient locations, with no known receptors or other ground-water users.

The Navy continues to support the hydraulic gradient provided with the draft report, based on ground-water elevations provided in Figure 3. A sensitivity analysis was completed using the suggested modification to the hydraulic gradient (i.e., 50 percent increase from 0.0073 to 0.1095 ft/ft). No significant changes in either the migration potential or years to source depletion were observed.

16. ***Table 6, Bioscreen Modeling Results from Instantaneous Reaction Simulation***—According to the notes, the maximum concentration of TPH-DRO used in the simulation is 10,000 µg/L. In Table 2, under Source Data, a value of 20 mg/L is given for the eastern TPH-DRO plume. It appears as the latter value is correct. Please correct the note and modeled times (if necessary). Also, check on the first page of Appendix C and determine if the 10 mg/L is correct for the DRO-east prediction. Also, the (a) and (b) footnotes do not correlate properly with notations in the body of the table.

    Response—Comment noted. After a review of both Table 2 and Table 6 an error was observed in Table 2 under Source Data for the eastern TPH-DRO plume. The listed value of 20 mg/L was incorrect and has been replaced with the correct value of 10 mg/L. A review of the first page of Appendix C was conducted and the Source Data input of 10 mg/L was correct for the DRO-east prediction. The (a) and (b) footnotes in Table 6 will be edited to correlate properly with notations in the body of the table.

17. ***Table 7, Bioscreen Modeling Results from First-Order Decay Simulation***—Same situation as the first part of the above Comment 16.

    Response—Comment noted. After a review of both Table 2 and Table 5, the listed Source Data were correct. A review of Appendix B was conducted and the Source Data input of 20 mg/L was correct for the GRO-east prediction, and the Source Data input of 10 mg/L was correct for the GRO-west prediction.

Attachment A

Model Sensitivity Analysis

MODEL SENSITIVITY ANALYSIS

Plume and Contaminant Type	Input Parameter Version	Source Zone Depth (ft)	Hydraulic Gradient (ft/ft)	Porosity (-)	Seepage Velocity (ft/yr)	Instantaneous Reaction		1st Order Decay	
						Maximum Migration (ft)	Time to Source Depletion (yr)	Maximum Migration (ft)	Time to Source Depletion (yr)
TPH-GRO East	Original	3	0.0073	0.35	136.0	300	12	500	2,250
TPH-GRO East	MEDEP 1	3	0.0073	0.25	190.3	300	12	700	2,250
TPH-GRO East	MEDEP 2	3	0.01095	0.35	203.9	300	8	700	1,500
TPH-GRO East	MEDEP 3	3	0.01095	0.25	285.5	300	8	900	1,500
TPH-GRO East	MEDEP 4	5	0.0073	0.35	136.0	300	12	500	2,250
TPH-GRO East	MEDEP 5	5	0.0073	0.25	190.3	300	11	600	2,250
TPH-GRO East	MEDEP 6	5	0.01095	0.35	203.9	300	8	700	1,500
TPH-GRO East	MEDEP 7	5	0.01095	0.25	285.5	300	8	900	1,500
TPH-GRO West	Original	3	0.0073	0.35	136.0	300	9	500	6,100
TPH-GRO West	MEDEP 1	3	0.0073	0.25	190.3	400	9	600	6,100
TPH-GRO West	MEDEP 2	3	0.01095	0.35	203.9	300	6	600	4,100
TPH-GRO West	MEDEP 3	3	0.01095	0.25	285.5	400	6	900	4,100
TPH-GRO West	MEDEP 4	5	0.0073	0.35	136.0	300	9	500	6,100
TPH-GRO West	MEDEP 5	5	0.0073	0.25	190.3	400	9	600	6,100
TPH-GRO West	MEDEP 6	5	0.01095	0.35	203.9	300	6	600	4,100
TPH-GRO West	MEDEP 7	5	0.01095	0.25	285.5	400	6	900	4,100
TPH-DRO East	Original	3	0.0073	0.35	136.0	500	41	800	3,900
TPH-DRO East	MEDEP 1	3	0.0073	0.25	190.3	500	41	1,100	3,900
TPH-DRO East	MEDEP 2	3	0.01095	0.35	203.9	500	28	1,200	2,600
TPH-DRO East	MEDEP 3	3	0.01095	0.25	285.5	500	28	1,600	2,600
TPH-DRO East	MEDEP 4	5	0.0073	0.35	136.0	500	41	800	3,900
TPH-DRO East	MEDEP 5	5	0.0073	0.25	190.3	500	41	1,100	3,900
TPH-DRO East	MEDEP 6	5	0.01095	0.35	203.9	500	27	1,200	2,600
TPH-DRO East	MEDEP 7	5	0.01095	0.25	285.5	500	27	1,600	2,600
TPH-DRO West	Original	3	0.0073	0.35	136.0	800	29	800	2,750
TPH-DRO West	MEDEP 1	3	0.0073	0.25	190.3	1,000	29	1,100	2,750
TPH-DRO West	MEDEP 2	3	0.01095	0.35	203.9	800	19	1,200	1,900
TPH-DRO West	MEDEP 3	3	0.01095	0.25	285.5	1,000	19	1,600	1,850
TPH-DRO West	MEDEP 4	5	0.0073	0.35	136.0	800	29	800	2,750
TPH-DRO West	MEDEP 5	5	0.0073	0.25	190.3	1,100	29	1,100	2,750
TPH-DRO West	MEDEP 6	5	0.01095	0.35	203.9	800	19	1,200	1,850
TPH-DRO West	MEDEP 7	5	0.01095	0.25	285.5	900	19	1,600	1,850